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**River Basin
Planning Staff**

Soil
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Davis,
California

MARCH 1989

WESTSIDE STREAM GROUP

PANOCHE CREEK SALINITY STUDY

FRESNO COUNTY, CALIFORNIA

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WESTSIDE STREAM GROUP
PANOCHE CREEK SALINITY STUDY

Fresno County, California

A part of
CALIFORNIA SPECIAL STUDIES
BASIN AND AREA PLANNING

FINAL REPORT

March 1989

Prepared by:
USDA, River Basin Planning Staff
Soil Conservation Service
Forest Service
Davis, California

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LIST OF PREPARERS

Technical studies and participation leading to the publication of this report were performed by the following:

USDA-SOIL CONSERVATION SERVICE

River Basin Planning Staff

Romeo A. Rivera, Staff Leader
Randall Godden, Team Leader, Forester, Forest Service
Doug Osugi, Civil Engineer
William Cunningham, Resource Conservationist
Allen Winans, Geologist
Stan Moorhead, Civil Engineer
Ken Murray, Economist
Tim Kuhn, Economist
Tom Share, Civil Engineering Technician
JoAnn Reid, Editor and Typist
Maha Aldoori, Typist
Betty Shatto, Typist

Others

John Beyer, District Conservationist, Fresno
Frank Menezes, District Conservationist, Hanford
Richard Herriman, Asst. State Soil Scientist, Davis
Dan Johnson, Area Engineer, Fresno

In Cooperation With:

California Department of Food and Agriculture

Vashek Cervinka, Research Manager
Agricultural Resources Branch

Westside Resource Conservation District

John Diener, President
Gerald Stoltenberg, Director

Under Coordination of the USDA Field Advisory Committee

Eugene Andreuccetti, Chairman, SCS, Davis
Robert Erwin, Member, Forest Service, San Francisco

SUMMARY

In March 1986, with the "plugging" of the San Luis Drain imminent in June 1986, the Westside Resource Conservation District requested a River Basin Study to investigate the potential for disposing of agricultural drain water by irrigating salt tolerant trees. A letter of support from the Westlands Water District indicated their interest in using eucalyptus or casuarina in conjunction with a selenium removal plant for recycling of agricultural drainage water. The California Department of Food and Agriculture expressed their interest in the economics of tree biomass production, harvesting and conversion into marketable commodities.

PROBLEM STATEMENT

On the west side of the San Joaquin Valley, more than one-half million acres of the nation's richest farmland are affected by salt buildup in the soil and the management and disposal of agricultural drain water.

The high levels of selenium and other elements, which are believed to cause deaths and chick deformity of waterfowl using the Kesterson Reservoir, has led to the closing of the San Luis Drain.

Without salinity and ground water management, growers in the study area will experience significant declines in most crop yields over the next 30 years. Ultimately, many fields may go out of crop production.

POSSIBLE CURRENT ACTIONS

An acceleration of on-going irrigation water management efforts would reduce the total volume of drain water produced and the amount of water added to the water table. Recycling and mixing of drain water with fresh water, and the ability of growers to manage their crops offer temporary solutions until the issue of disposal can be resolved.

POSSIBLE FUTURE ACTIONS

The development of increased salt tolerance in conventional crops, like cotton or barley, is being explored. Introduction of alternative crops is unlikely in the next 20 years because cotton and barley will continue to produce relatively good yields. Salt tolerant and alternative crops, however, do not solve the problem of salt buildup in the soil or disposal. Within about 10 years, some economic form of salt removal will be needed. Disposal of drain water to nearby locations away from the prime agricultural areas was considered in this study but found to be economically infeasible as well as environmentally questionable.

AGROFORESTRY

The term "agroforestry" is used to describe the integration of trees with other agricultural operations. This generally means woodlot, shelterbelt or windbreak applications in combination with crops and animals. The commercial production of wood products on agricultural lands has been successfully used in other parts of the world with similar problems, and can be useful in the San Joaquin Valley.

An on-going demonstration program shows that tree plantations have a high potential for managing both drain water and high water tables. The extensive root systems and leaf areas of some trees can absorb and evapotranspire large amounts of water.

This report shows that under certain situations, agroforestry can reduce the amount of drain water that will ultimately need to be disposed. Tree plantations can use up to 6 acre-feet of drainwater per acre per year.

Market Choices

Several markets are available:

1. Export of chips from Stockton deepwater port
2. Pulp chips for paper manufacturing in Antioch
3. Firewood for the San Francisco/Los Angeles areas
4. Biomass for power generation at Mendota

Local firewood markets are also active. Emerging markets like industrial feedstock for conversion into fuels or chemicals are additional possibilities to consider as they develop. The combined demand for these markets varies between one and three million cords per year and is large enough that no depression of present prices from a moderate increase in supply is expected.

Recommended Species & Yield

Tree plantations with river red gum (Eucalyptus camaldulensis) can produce commercial crops if irrigated with recycled drain water. This species will tolerate all expected climatic and soil conditions in the study area. In plantations with both water table and salinity problems, plantations stocked with 1,200 trees per acre will yield an estimated 3.5 cords (or 7 dry tons) per acre per year when irrigated with recycled drain water.

Appendix A entitled "Agroforestry" presents data that a potential producer of wood products needs to consider before embarking upon such a venture. Criteria on species selection and recommendations, the cultural practices that are involved, plantation management and harvest, and expected eucalyptus growth and yield tables are discussed.

Alternative Systems

Three basic systems of disposal were evaluated in this report:

System 1. Evaporation pond
System 2. Evaporation pond with eucalyptus plantation
System 3. Evaporation pond, eucalyptus plantation and regulating reservoir.

Appendix C: Economic Evaluations and Appendix D: Engineering describe these systems and provide example layouts in more detail.

Table A-1 gives a summary comparison of land use, income, installation costs, average annual cost, and average annual cost per acre-foot to install three waste disposal systems. The data is for comparison purposes only, since the level of investigation was very low intensity. Detailed investigations using site specific information would have different results in most cases. For example, using a lower drainage yield would result in a lower need for eucalyptus acreage, smaller sized evaporation ponds and regulating reservoirs, lower installation costs, and greater net incomes and land devoted to cropland.

TABLE A-1 - SUMMARY COMPARISON
(160-acre evaluation unit, High Regional Drainage Yield)

	System 1	System 2	System 3
Cropland (acres)	135	133	131
Eucalyptus (acres)	0	20	15
Ponds/reservoirs/facilities (acres)	25	7	14
Net Present Value Income ($1000)			
w/Unlined pond	97	106	29
w/Lined pond	-1356	-276	-285
Installation Cost ($1000)			
w/Unlined pond	44	35	98
w/Lined pond	1494	416	380
Average Annual Cost ($1000)			
w/Unlined pond	6	6	13
w/Lined pond	138	40	39
Average Annual Cost/AF of cropland drained ($)			
w/Unlined pond	60	60	135
w/Lined pond	1355	410	400

Risks and Uncertainties

There are a number of risks and uncertainties that must be considered. They are discussed under Economic Evaluations in the report, the Engineering Appendix and are summarized below:

1. The effect of salinity buildup in the soil and the impact on yields from woodlots without an installed drainage system is an unknown and potential problem.

2. The future acceptability of open evaporation ponds is unknown. Ponds may contain illegal concentrations of toxic materials that may require clean up later. It is likely that future requirements will greatly increase the cost of evaporation ponds, clean up by removal of soil, and disposal to suitable sites. These costs are difficult to predict and these risks must be considered by the farmer before installing basins.

3. Another area of uncertainty is how salt and other dissolved solids like selenium will affect market suitability of the wood. Current studies indicate that eucalyptus has a low level of salts in their tissues. If selenium is volatized when burned, it could be a potential air quality problem or greatly increase burner cleaning and maintenance costs.

4. Estimates of total water use by eucalyptus vary widely. The risk involved is in the design or overdesign and its impact on the costs of waste disposal systems.

5. How eucalyptus will tap into and utilize groundwater will depend upon the nature of the soils and how water moves through them. Close drain pipe spacing increases the likelihood that tree roots will invade and block the pipe, resulting in additional costs for maintenance or replacement.

6. How the dissolved solids content of the ground water affects water uptake is presently unknown. If some water uptake problems develop during the life of the plantation, it may be necessary to occasionally irrigate with fresh water to flush the salts.

7. The analysis assumes all land in the study area that needs to be drained will be drained. If this is not the case, those landowners with installed drainage will have much higher drainage yields because of lateral movement from fields upslope. The analysis indicates that a collective or project-type approach is needed to uniformly address the problem.

SUMMARY CONCLUSIONS:

1. Agroforestry is an interim practice and not a long term solution to the perched water table problem. This approach reduces the amount of land lost to production and the volume of water to be disposed of by other long term methods.

2. There are a number of risks and uncertainties discussed above that need serious consideration, when considering agroforestry and the production of woodlots as part of a farming operation.

3. Woodlots can reduce the volume of drain water that needs to be evaporated or ultimately disposed of by about 75 percent.

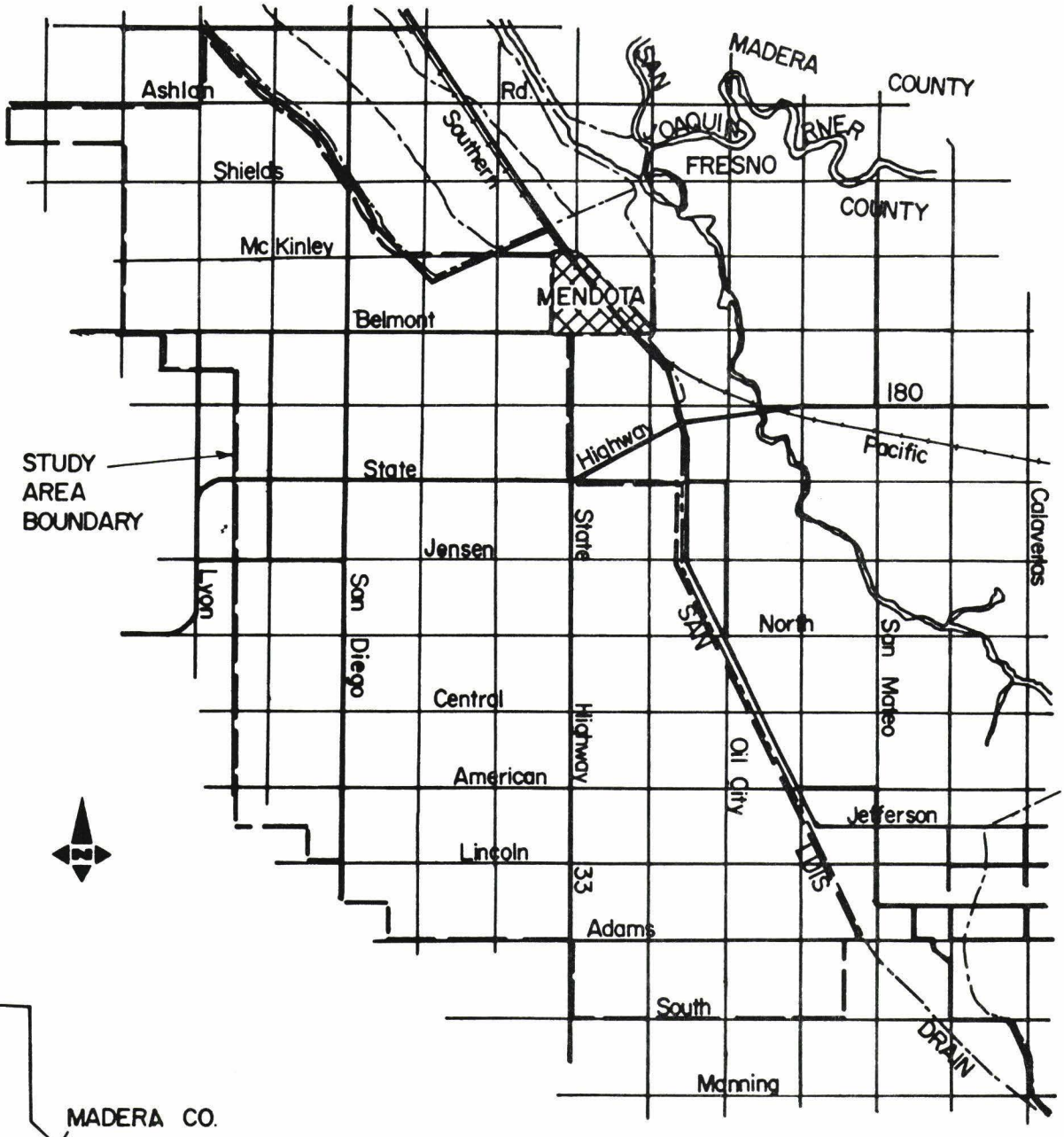
4. If the ponds do not need to be clay lined, all three systems are cost effective under certain conditions. If lining is required, none of the systems evaluated are cost effective.

5. Incorporating a eucalyptus plantation in conjunction with an evaporation pond (System 2) provided the greatest net returns of all the systems evaluated. It allows the maximum number of acres to be in production, but with associated risks.

6. The additional cost of a regulating reservoir in System 3 to provide the flexibility for proper water management for maximum drainage water volume reduction resulted in a lower net income.

7. There are strong firewood, pulpwood, and biomass markets to purchase the anticipated amounts of wood fiber products in the area. A typical grower with average production costs and zero land rent can direct market firewood for $120 per cord and realize a rate of return on their investment of 12.4 percent. Using an 11 percent cost of money, the tree plantation income will be worth a net present value of $282 per acre.

8. Several landowners or groups of landowners may be able to combine their efforts into a larger project area. Engineering and management efficiencies would probably reduce construction and operation and maintenance costs. Location of disposal areas of lowest environmental sensitivity can also minimize environmental impacts. This aspect was beyond the scope of this study, but deserves further study.



INDEX MAP

FIGURE A

LOCATION MAP

WESTSIDE STREAM GROUP

PANOCHE - SILVER CR. UNIT

California

INTRODUCTION

AUTHORITY

Cooperative River Basin Studies have been conducted by the U.S. Department of Agriculture (USDA) in California for many years. The USDA is authorized by Section 6 of the Watershed Protection and Flood Prevention Act, Public Law 566 of the 83rd Congress, 68 Stat. 666 as amended, to provide planning assistance to federal, state, and/or local agencies. These studies focus on specific water, land, and related resource problems and solutions which may include erosion and sedimentation, flooding, irrigation, drainage, water quality, water supply, recreation, fish and wildlife, and other concerns. This study was done under the ongoing "California Special Studies" authorization.

The River Basin Study was requested by the Westside Resource Conservation District (WRCD), which is responsible for the stewardship of soil and water conservation activities in the area. The study is co-sponsored by the California Department of Food and Agriculture, and a letter of support has been received from the Westlands Water District.

BACKGROUND AND PURPOSE OF THE STUDY

In March 1986, with the "plugging" of the San Luis Drain imminent in June 1986, the Westside Resource Conservation District (RCD) requested a River Basin Study to:

(1) Investigate the potential for disposing of drain water, both on-farm and off site, by irrigating salt tolerant trees, shrubs, or grasses.

(2) Determine whether woodlot production of trees like eucalyptus, casuarina, poplar, and tamarisk is an economically viable venture in the Westside RCD area.

(3) Determine the economic feasibility of pumping drain water to less productive soils and to suitable disposal areas in the upper watershed where income from irrigated crops can be used to offset pumping costs.

On May 13, 1986, the SCS River Basin Staff met with representatives of the Bureau of Reclamation, California Department of Food and Agriculture, and the Central Valley Regional Water Quality Control Board to discuss the proposed study. It was generally agreed that the study was needed to substantiate assumptions presently made, and would complement other on-going studies.

A meeting with the Westlands Water District in June 1986 and a subsequent letter indicated their support for the study. They were interested in the use of vegetation in conjunction with a selenium removal plant for recycling of agricultural drainage

water. Westlands had explored pumping the drain water to off-site locations, but found it infeasible due to the high costs involved ($200 to $300 per acre-foot). This confirmed the preliminary estimates of the River Basin Planning Staff, and this objective was dropped from the study.

A July 1986 letter was received from the California Department of Food and Agriculture (CDF&A) indicating their interest in the economics of tree biomass production, harvesting, and conversion into marketable commodities.

OBJECTIVES AND SCOPE OF THE STUDY

Based on the initial request, scoping meetings and literature search, the study focused on the economic viability of woodlot production of eucalyptus.

As the study progressed and more information became available, the initial scope of the study was expanded to include tree plantations which were either irrigated with drain water or allowed to utilize shallow ground water. An additional objective was added to investigate, in detail, the use of tree plantations in combination with evaporation ponds for the disposal of agricultural drain water.

STUDY AREA

The study area is located on the west side of the San Joaquin Valley in Fresno County. Panoche and Silver Creeks originate in the Diablo Range and have formed a large spreading alluvial fan southwest of the city of Mendota. The watershed is sparsely populated,with ranching and farming being the main enterprises.

The 42,000-acre study area is that portion of the Westlands Water District which has a completed collector drain system. It includes about 5,000 acres with on-farm drainage systems installed. The area is located east of Interstate 5 and west of the San Joaquin River. The study area is bounded on the south by Adams and South Avenues, and on the north by Ashlan Avenue.

The climate of the area is semi-arid, with temperatures climbing to over 100 degrees in the summer months. Winters are relatively mild, with periodic freezing temperatures. Average rainfall is about 8 inches in Mendota, but the upper watershed to the west of the study area averages nearly 16 inches. Most of the rainfall occurs between October and April. Rainfall is so rare during the summer months that irrigation is vital for crop production.

Soils in the lower portion of the watershed between the San Joaquin River and the San Luis Drain (Figure B) are used primarily for wildlife habitat, recreation, and growing saline-sodic tolerant irrigated field and row crops. The three representative soils are Columbia, Tachi, and Lillis. High salinity and sodicity is a naturally occurring problem for the Lillis and Tachi soils.

SOIL LANDSCAPE PROFILE

Panoche Creek
California

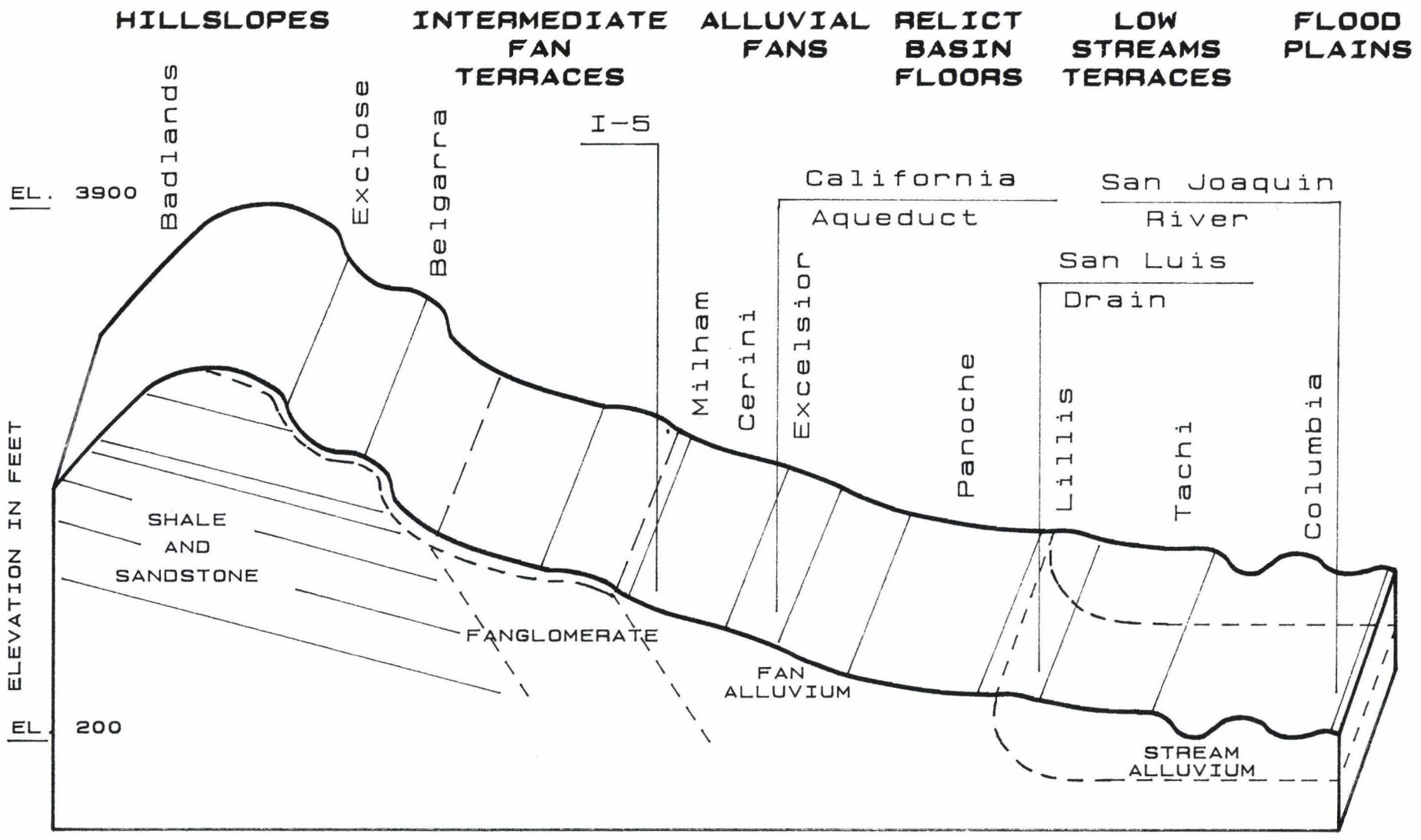


FIGURE B

Panoche and Excelsior soils are common between the San Luis Drain and the California Aqueduct (See Figure B) and are used primarily for growing irrigated saline-sodic tolerant field and row crops such as cotton, alfalfa, tomatoes and corn. Salinity and sodicity are minor problems. The water table is perched and ranges between 5 to 10 feet below the ground.

In the area between the California Aqueduct and Interstate 5, the predominant soils are Cerini and Milham which are used for growing field and row crops such as cotton, barley, wheat, alfalfa, tomatoes, onions, garlic, and cantaloupes. Almonds are also grown in some areas. Soil salinity is low [EC less than 2 milli Siemens/centimeter (mS/cm)] and the water table is below 5 feet.

Boron, selenium and asbestos are naturally occurring elements in the marine shale formations which occur in the upper watershed (Badlands, Exclose and Belgarra Soil Series). Erosion and weathering of these shales has been occurring for thousands of years, with the sediments being deposited in large fans reaching from the foothills well into the San Joaquin Valley floor. See Soils appendix for more information.

PROBLEM STATEMENT

On the west side of the San Joaquin Valley, more than one-half million acres of the nation's richest farmland are affected by irrigation induced salinity and drainage problems. If the problems associated with the managing and disposal of agricultural drain water are not solved, much of this land will eventually be forced out of crop production.

This area is underlain by a series of clay layers which prevent deep percolation of irrigation water. Over the years, this irrigation has caused perched, saline waters to encroach into the crop root zone and reduce both the crop yields and the variety of crops which can be planted. This basic problem has been further complicated by the presence of potentially toxic trace elements like boron, selenium, strontium and copper. These elements are typically present in concentrations which are not normally dangerous to animals, but can be accumulated by vegetation or invertebrates in the food chain to levels which are toxic to animals feeding on them. These elements can also be concentrated to potentially harmful levels by evaporation, which makes the management and disposal of the subsurface saline waters very difficult.

These salts have been managed for agriculture by leaching, and thus flushing them into the subsoil beyond the crop root zone. Because of the underlying impermeable clay layers, the leaching causes the water table to rise and the production of crops is diminished. Growers can cope with this by managing the water table and planting more salt tolerant crops, such as barley and cotton, but over time farm profits will decline. To halt this,

drainage can be installed to keep the saline water from the root zone and maintain crop production.

In 1960 the State Water Project and Federal Central Valley Project were authorized for construction and contained provisions for drainage of a portion of the San Joaquin Valley. The San Luis Drain was to be constructed to take the saline drain water to an outlet in the San Francisco Bay/Sacramento-San Joaquin Delta estuary and then into the Pacific Ocean. By 1975, 85 miles of the San Luis Drain had been constructed and the Kesterson Regulating Reservoir completed. The U.S. Fish and Wildlife Service was authorized to develop the reservoir as a National Wildlife Refuge (NWR).

From 1978 to 1984, over 7,000 acre-feet of drain water flowed annually via the San Luis Drain to Kesterson. Limited funding and environmental concerns about increasing salinity and pollution of San Francisco Bay prevented the planned completion of the San Luis Drain from the Kesterson Regulating Reservoir. During that same period, Westlands Water District installed a drain water collection system for over 42,000 acres. Individual growers installed on-farm drainage systems for 5,000 acres within that same area. In 1980, the Bureau of Reclamation applied for a permit to discharge the drain water into the Delta, and the California State Water Quality Control Board set the discharge requirements. The investigations and technical studies, which were required as part of the permit issuance process, disclosed high levels of selenium and associated elements in both Kesterson Reservoir and the drain water flowing into the San Luis Drain. By 1984, these elements were causing both waterfowl death and chick deformity at Kesterson NWR. A program of hazing was begun to keep waterfowl from using the refuge, and an inter-agency team was formed to evaluate alternatives to solve the drainage problems throughout the San Joaquin Valley.

Because of the environmental problems centered around Kesterson National Wildlife Refuge, the Department of the Interior ordered that all drain water delivery into the San Luis Drain be halted by June 1986. The Westlands Water District plugged its collector system, stopping water delivery to the San Luis Drain. Westlands Water District board members stated in their Environmental Impact Report (EIR) the environmental and economic impacts of drain plugging cannot be fully mitigated until drainage water treatment and disposal can be implemented. Drainage discharge into the San Joaquin River and its tributaries has increased since the cessation of discharge to the San Luis Drain.

POSSIBLE CURRENT ACTIONS

The most immediate action possible is the intensified management of irrigation to minimize the amount of water added to the water table. This also minimizes the amount of salts imported into the area. This action will extend the productivity of the area, especially with the shifting to salt tolerant crops.

Careful irrigation water management can reduce the amount of drain water produced; although for salinity management purposes, some leaching is still required. For example, alfalfa requires an average of 0.5 acre-feet/year and cotton 0.3 acre-feet/year of leaching water per crop acre, even under the best water management. Mixing drain water with fresh water can be used in the short term with salt-tolerant crops like cotton; however, over time soil salinity will still increase.

Using an average drain water yield of one-third acre-foot per crop acre, the 42,000-acre study area will potentially yield approximately 10,000 acre-feet of drain water for disposal (allowing for roads, improvements, unirrigated crops, or fallow land). The perched water being drained generally ranges in quality between 6,000 and 15,000 parts per million (ppm) of total dissolved solids (TDS). For comparison, sea water is about 35,000 ppm TDS. The major cations are sodium, calcium, or magnesium and the anions are sulfate, chloride, or bicarbonate. Evaporation yields mostly a sodium sulfate salt. While varying widely throughout the area, the major trace elements are boron, strontium, and selenium (averaging about 15 ppm, 7 ppm, and 0.3 ppm, respectively).

The Westlands Water District has developed a three-phase program to reduce the levels of boron and selenium in the drain water. Phase one developed a prototype plant. Phase two will be to construct a prototype plant. The last phase will be a full-scale plant capable of treating 10,000 acre-feet per year. What to do with the still saline water has yet to be resolved and is being studied by the Westlands Water District. Among the alternatives are evaporation ponds, deep well injection into a saline aquifer, solar ponds (a way to use the heat of the sun to generate electricity), and reverse-osmosis desalinazation.

FUTURE WITH NO ACTION

Without salinity and ground water management, growers in the study area will experience significant declines in most crop yields over the next 30 years. When these fields go out of production, native habitat and wildlife (possibly endangered species) will eventually benefit. Ultimately, many fields may go out of crop production. According to Westlands Water District, the electrical conductivity (EC) of delivered irrigation water is 0.3 to 0.4 milli Siemens per centimeter (mS/cm). Even though this is very good quality water, salt will eventually build up to concentrations that reduce yields if not leached from the root zone of plants. Each crop has a maximum EC threshold level which will allow profitable production. In addition, the shallow water table limits the active root zone of the plants or crops. If salt levels in the soil cannot be reduced by leaching and water tables cannot be lowered because drainage is restricted, salt levels in the soil and ground water will increase and reduce the amount of water the plant is able to utilize. If the salt levels are too high, crop yields will be reduced, and eventually the crop will fail to produce commercial yields.

Most crop yields are not affected if the EC of the soil does not exceed 2 mS/cm. Crops such as onions, lettuce, corn, tomatoes, grapes, and alfalfa will begin to decline in yield when the EC exceeds 2 mS/cm. Wheat begins to decline at an EC of 6 mS/cm. Cotton and barley are among the most salt-tolerant crops and can tolerate an EC of 8 mS/cm before yields are reduced.

Since the drainage collector system in the study area has been closed, other methods to manage the saline water table are being used. In 1986, recycling of drainage water was undertaken on 13,800 acres of the drainage service area. According to the Westlands Water District's Water Conservation and Management Handbook, "Recirculating drainage water is a short-term solution and does not solve drainage problems. The leached salts are only returned to the soil profile with the irrigation water." Graphs in the handbook show the projected increase in the EC of a slightly saline (2.5 mS/cm) and a moderately saline (6.0 mS/cm) 4-foot soil profile over time, and the resultant decrease in yields of various crops grown in the study area. The slightly saline soil (2.5 mS/cm) will increase to an EC of 8 mS/cm in 12 years, while the moderately saline soils will increase to an EC of 8 mS/cm in 5 years using recirculated water.

Westlands Water District projections show that beans, onions, and lettuce would go out of production in 8 years, 9 years, and 15 years, respectively, on slightly saline soils. Corn, grapes, tomatoes, safflower, and melons would go out of production in 18 to 22 years. Cotton and barley, with high salt tolerances, would go out of production in approximately 50 years on slightly saline soils. Cotton and barley on moderately saline soils would go out of production in approximately 45 years.

As the soils information implies, there are already large areas which are moderately salt affected and can only grow the more salt tolerant crops like cotton. Westlands Water District reports the following approximate land use for the 42,000-acre study area:

Estimated Average Crop Acreage

Crop	Percent
Alfalfa	5
Barley	6
Cantaloupe	4
Cotton	50
Tomatoes	10
Wheat	10
Fallow	6
Misc. (almonds, beans, corn, garlic, lettuce, safflower, sugar beets)	9

Two previous studies conducted by the Soil Conservation Service in the San Joaquin Valley on nearby areas with similar problems also indicate that eventually a high proportion of the land in the study will go out of crop production. In the Leland-Freeborn watershed located south of the study area, it was estimated that 2,800 acres had already been lost, and an additional 13,200 acres, or nearly 70 percent of the study area, would go completely out of production within 50 years. The South Fork of the Kings River (SFKR) study estimated that over 60 percent of the 37,000-acre study area would revert to native vegetation within 40 years. At present the SFKR has 90 percent of its acreage in either cotton or barley. Both these studies concluded that drainage and unlined evaporation ponds were the most cost-effective interim solution available. The South Fork Kings River study did indicate that trees in combination with evaporation ponds could reduce the amount of drain water which would need to be evaporated. These reports and the Draft EIS for drainage system plugging in the Westlands Water District estimate that after approximately 10 years of drain water recycling, only cotton and barley will be in commercial production.

POSSIBLE FUTURE ACTIONS

Crop Improvement

The development of increased salt tolerance in conventional crops, like cotton or barley, is being researched by several universities and public agencies. Progress is being made and, as plant selection and gene splicing techniques are improved, considerable progress is possible in the long term. For example, one research project goal is to develop a variety of barley which can be irrigated with sea water, but results are not expected for at least 5 to 10 years. Crop improvement, however, is an interim solution since it does not address the problem of salt buildup in the soil or disposal.

Alternative Crops

Introduction of alternative crops (as an interim solution) is unlikely in the next 20 years because cotton and barley will continue to produce relatively good yields. New crops would mean that new markets and probably new processing technologies would have to be developed. Most farmers would prefer to grow their present crops as long as possible to avoid the uncertainty involved with new crops.

Salt Removal

Within about 10 years, some economic form of salt removal will be needed. Possible existing technologies like evaporating concentrated drain water and utilizing the remaining compounds will be a key element. Some type of desalinization will be a part of the long-term maintenance of agricultural productivity. The present limitation in this technology is its cost

effectiveness. The California Department of Water Resources (DWR) was investigating a large-scale reverse-osmosis desalting facility. The program grew out of the results from DWR's pilot plant facility near Firebaugh, California. DWR operated a test facility at Los Banos, California, from 1984 to 1986. The results of this led to a cooperative program with Westlands Water District, where a small-scale test plant will be constructed in Mendota, California, in the near future. This could lead to a full-scale desalting facility by 1995 or 2000.

Export Drain Water

Disposal of drain water away from the prime agricultural areas was considered at a reconnaissance level of intensity. A site was identified which did not have clay layers or other infiltration problems, and was in an isolated aquifer already too salty for domestic or agricultural use. A site over this isolated "unusable" aquifer would eliminate the need for a costly drainage water collection and return system. Such a site ensures that drain water would not mix with fresh water aquifers of the San Joaquin Valley or adjacent valleys to the west.

The energy cost alone to pump drain water from the San Luis Drain to the selected sites varies from $44 per acre-foot at the California Aqueduct to nearly $125 per-acre foot just west of Interstate 5 to $438 per acre-foot at a possible site with an acceptable aquifer northwest of Panoche Valley. These figures do not include any pipe beyond that presently located along Adams Avenue, so in actuality the cost per acre-foot would be even higher than shown.

A low elevation site located at Adams Avenue and the San Luis Drain would have much lower pumping costs and could utilize the existing pipe system, and is being studied by the Westlands Water District. Should this alternative prove infeasible for some reason, further consideration of other sites may be justified.

Disposal of drain water over an aquifer outside of the prime agricultural area was infeasible because of the high pumping costs and the need for extensive conveyance and distribution systems. These costs would not be offset by wood fiber production from the water. Pumping to areas near or above I-5 were much more costly and offered no advantage over present alternatives being studied by Westlands Water District or evaporation pond systems for individual farms. Detailed information on these alternatives is contained in the EIR and EIS for Westlands Water District's programs. The value of maintained production on the present agricultural lands was not included in this part of the study as that they are not expected to go completely out of crop production for 40 or more years.

Agroforestry

The commercial production of wood products on agricultural lands (also termed "agroforestry") has been successfully used in other

parts of the world with similar problems, and can be useful in the San Joaquin Valley. A demonstration program was initiated by the Soil Conservation Service, California Department of Food and Agriculture, Westside RCD, and several universities, groups and individuals to assess the potential of agroforestry in the area. This demonstration program will develop more information on how agroforestry might best be incorporated into farming operations. The program will also collect specific information on the environmental effects of introducing large acreages of trees into the area.

Initial results from the demonstration program show that tree plantations have a high potential to help in the management of both drain water and water tables. The extensive root systems and leaf areas of some trees can absorb and evapotranspire large amounts of water. Under some conditions, the trees can use more water than can be evaporated from an open water surface.

This combination of tree plantations and commercial agricultural crops is widely used outside the United States, and is generally called agroforestry. The term "agroforestry" implies the application of intensive agricultural techniques to traditionally forestry-related crop species and products. In California this generally means the short rotation management of relatively dense tree plantations which are cultivated, irrigated, and fertilized to produce pulpwood, firewood, or biomass for power production and industrial fiber. Trees can be planted on lands which have become unsuitable or uneconomical for the production of other commercial agricultural crops. This kind of agroforestry is relatively common in areas of wood shortages for heating, cooking, or industrial purposes; but is only now being integrated into the food and fiber production base of the United States.

In a broader sense, the term "agroforestry" is commonly used to describe the integration of trees with other agricultural operations. This generally means woodlot, shelterbelt or windbreak applications in combination with crops and animals; the intent being to diversify the farming enterprise and minimize the need for intensive chemical applications by utilizing natural systems as much as possible (e.g., graze down weeds instead of spraying with herbicides).

The recommended species for the area is river red gum (Eucalyptus camaldulensis). Specific cultural and management recommendations are included in Appendix A. The trees should be machine planted in a prepared site at a stocking rate of 1,200 trees per acre. Planting casuarina around the perimeter for wind protection is also recommended. Actual management will vary depending on the product chosen to market. Harvesting will vary from every 5 to 10 years, depending on the managers' objectives and the quality of the site.

Estimated yield of firewood ranges from 3.5 cords/acre/year to 5 cords/acre/year, depending on salinity, cutting intervals, and

site quality. Total estimated fiber yield similarly ranged from 7 to 10 bone-dry tons/acre/year. The wood fiber produced will be suitable for firewood, pulpwood, power generation fuel (biomass) or cellulose feedstock for industrial uses such as manufacturing plastic.

The exact role of tree plantations in the San Joaquin Valley is still being explored. In some areas, selected tree species can be used by themselves to help reclaim salt or water table affected lands. In other areas, plantations can be irrigated with moderately saline water (not exceeding 12,000 ppm TDS) drained from surrounding fields. Once established, these plantations will use an estimated average of 5 to 6 acre-feet of water per acre, depending on local conditions. The plantations can then be drained into evaporation ponds for disposal. This allows the production of a fiber crop on land which might otherwise have to be used to evaporate drain water.

Agroforestry is an interim practice and not a long term solution to the perched water table problem. This approach reduces the amount of land lost to production and the volume of water to be disposed of by other methods. The importance of a long term solution of salt removal cannot be over emphasized.

ECONOMIC EVALUATIONS

The evaluations used a range of markets, costs, yields, interest rates, and incomes to show conditions and choices reasonably available to growers. Decision tree diagrams are included in the Economics Appendix which will allow growers to get an estimate of their rate of return on investment (RRI) or their net present value (NPV) for a variety of situations. The diagrams are provided for three market choices: firewood, pulp chips, or biomass chips. Each diagram has an average cost or a low cost choice. The average cost choice is designed for those growers who plan to irrigate the plantations with drain water and must plant a more expensive seedling ($.20), which has been selected for vigor from a salt tolerant seed source. The low cost choice is designed for those growers who plan to plant for water table management, so they will not have an irrigation cost beyond establishment and can buy the least expensive seedlings available ($.10 each).

Yields on average agricultural lands were estimated to be 5 cords/acre/year for firewood and 10 bone dry tons/acre/year for chips. Yields for salt affected areas or poorer agricultural lands were estimated at 3.5 cords/acre/year or 7 bone dry tons/acre/year. Each diagram branch has this choice for high or low yield.

The analysis used three land rents ($0, $40, and $120/acre) to allow a choice of commonly used rents, and two interest rates (5% and 11%) to show the effect of the cost of money.

A typical situation was where a grower planned to direct market the trees as firewood ($120/cord) with average production costs from salt affected land (3.5 cords/acre/year), which they owned (zero land rent). If the initial money was borrowed at 11 percent interest, they could expect a net rate of return on that investment of about 12 percent, or the plantation would have a net present value of about $282 per acre. This situation is shown by the dark line on the Firewood diagram in the Economics Appendix.

An example of the spread sheet used to develop this information is also included in the Economics Appendix as Table C-1. Individual growers should compare the figures on this spread sheet with their situation to gauge its appropriateness. The example is for firewood, but pulpwood or biomass are very similar. The differences would be in harvest timing, harvest costs, haul costs, and the price for chips when delivered. The analysis used a planning horizon of approximately 20 years. Harvest timing was a reasonable combination of seedling and coppice cuts, which give approximately equal yields and would be near the 20-year horizon.

Harvest and haul costs were developed from manufacturers' published cost data, estimates from local sources, or published

studies. Cost to fall, limb, buck, split (minimal), and stack for air drying of firewood was estimated at $35 per cord. Cost for hauling to either Los Angeles or San Francisco was estimated at $18.25 per cord, with an additional $5.65 per cord to load onto the truck. Morbark California, Inc. provided a cost per ton analysis for their Model 20 total chip harvester and required support equipment for felling/bunching and skidding. For biomass, the adjusted cost for harvest was $5.88 per green ton (40% moisture content wet basis). Hauling in a 20-ton chip van to Mendota was estimated at $2.25 per green ton. For a pulpwood quality chip, a Portable Mortran Screen was added to separate out leaves, bark and limbs, giving about 75 percent pulp chip yield. This increased the cost by $1.74 per ton to a total of $7.62 per green ton. Hauling to Antioch, California, was estimated to cost $11.25 per green ton. Most of the 144 combinations analyzed had positive rates of return and net present values. Some of the combinations were very good investments and deserve serious consideration by individual growers.

The typical situation described was used to further analyze the usefulness and economic practicability of combining trees with evaporation ponds for drain water disposal. The details of this analysis are also contained in the Economics Appendix and are displayed as a decision tree. The engineering aspects of this analysis are in the Engineering Appendix. The general engineering considerations revolved around the combinations of a lined or unlined evaporation pond, with or without eucalyptus plantations, with or without regulating reservoirs, and in areas with high or low regional (i.e. off-site) drainage yields.

Using the information developed, net present values were determined for both evaporation ponds and evaporation pond/plantation systems. This analysis was for a 160-acre unit and affected both the field crop income (cotton-cotton-wheat) and the eucalyptus income.

Pond lining was a major cost factor in this analysis. The need for lining must be on a site specific basis, and depends on the quality of the underlying ground water and the permeability of the underlying soil after compaction. When pond lining is required, no drain water disposal system provides a positive net present value using the economic assumptions of this analysis. All the alternatives with eucalyptus plantations were much better than the evaporation pond alone. This is due to the high cost of pond construction being reduced by the need for a smaller pond with these options.

The unlined evaporation pond only option shows the greatest net present value, with $140,000. This was closely followed by the unlined pond/plantation options, which all showed positive returns. This finding is similar to the findings of the Leland-Freeborn and South Fork of the Kings River studies located nearby in the San Joaquin Valley.

The analysis does not reflect the general environmental benefits of replacing a portion of the evaporation pond with a eucalyptus plantation. Recently published reports show that wildlife, in general, and waterfowl/shorebirds in particular, are attracted to the evaporation ponds for feeding, resting, nesting and cover. These animals can suffer from the same problems associated with the Kesterson National Wildlife Refuge. Anything which will reduce the need for evaporation ponds will have a positive environmental benefit to the San Joaquin Valley.

Several landowners or groups of landowners may be able to combine their efforts into a larger project area. Engineering and management efficiencies would probably reduce construction and O&M costs. Location of disposal on areas of lowest environmental sensitivity can also minimize environmental impacts. This aspect was beyond the scope of this study, but deserves further study.

RISK AND UNCERTAINTY

The effect which build-up of soil salinity will have on a woodlot without installed drainage is the most serious potential problem. The agroforestry demonstration plantings will be evaluated over a long enough period of time in order to gauge the effects of dissolved solids on woodlot yield. For purposes of this study, it was estimated that since eucalyptus is about twice as tolerant of salt as cotton, it would produce commercial yields about twice as long. The Environmental Impact Statement (EIS) for drainage system plugging in the Westlands Water District estimates that only cotton and barley will be in commercial production after 10 years of drain water recycling. Thus, it was estimated that eucalyptus would still be in commercial production for at least 10 years, even on salt affected fields. Recommended plantation management assumes that drainage has been installed in areas with shallow water tables, or that recommended layout allows for drainage installation should ground water levels rise and salt build-up need to be managed during the life of the plantation. The collection of drain water from extensive acreages for the irrigation of woodlots is infeasible without drainage and disposal on most soil types.

The future acceptability of open evaporation ponds is unknown. The USDI Fish and Wildlife Service has presented data indicating heavy use by waterfowl and shore birds of most evaporation ponds. Evaporation of water in ponds will almost always concentrate elements like boron and selenium to where death or deformity of bird populations can result. The Interagency Evaporation Pond Group has developed draft guidelines for agricultural subsurface drainage evaporation basins which will have an impact on pond design, construction techniques, and operation/maintenance. This report is a "snapshot in time" which does not include all possible future changes. It is likely that future requirements will greatly increase the cost of evaporation ponds, and make them less attractive as a disposal alternative. The intent of this report is to make a general economic comparison between different evaporation pond alternatives presently available, and

not to make recommendations on which alternative an individual grower may wish to install. The evaporation pond design included most of the design recommendations presently being considered. Salts remaining in the evaporation ponds are assumed to be removed at regular intervals for disposal in landfills accepting Class II hazardous wastes. Salt wastes may change to a more hazardous classification if toxics are also encountered. Abandoned evaporation ponds may need to be cleaned up by removal of soil, and subsequent landfill disposal.

Another area of uncertainty is how salt and other dissolved solids like selenium will affect market suitability of the wood. The basic reason that eucalyptus is able to tolerate high levels of salt is by excluding them from the water as it is absorbed into the root system. Studies indicate that the most salt-tolerant varieties of eucalyptus have a low concentration of salts in their tissue. This ability to exclude these salts was one reason that red river gum was selected as the recommended species to plant. Taken in context with other hardwoods presently being used for firewood in California, eucalyptus should not pose any greater problem than blue oak grown on soils derived from marine sediments (described earlier). Since millions of cords have been harvested off of these areas throughout California and burned without significant environmental problems, the harvest and burning of less than 25,000 cords per year of eucalyptus is estimated to be relatively safe.

The agroforestry demonstration program will sample and analyze wood from salt-affected plantings to determine tissue analysis. Preliminary results from the demonstration program show that selenium is taken up by river red gum. The concentration of selenium in trees irrigated with drain water were three to five times higher than comparable trees irrigated with fresh ground water. The stemwood had the lowest concentrations (100 to 200 parts per billion [ppb]). Leaf tissue had the highest concentrations, with up to 900 ppb. This ongoing study will determine the fate of selenium in biomass power generation plants, as this use presents the greatest potential problem because it burns the dried leaf tissue. If the selenium remains in the ash, it could be a valuable resource for industrial processes like glass manufacturing. If the selenium is volatilized when burned, it could be a potential air quality problem or greatly increase burner cleaning and maintenance costs. This potential problem is even less likely to occur where the wood is used for pulp, where only the stem is utilized.

Estimates of total water use by eucalyptus vary widely, depending on climate, tree density, and how the use rate is determined. Measurement of water transpired by individual trees in ventilated chambers give water use rates of up to 1.9 times the rate evaporated from an open pan. Studies at U.C. Davis, where water is made available to the trees by tensiometer controlled drip irrigations, give water use rates of approximately 80 percent of open pan rate. In general, high growth rates of trees will mean

high water use rates. These rapidly growing trees can be expected to use large amounts of water, certainly well above the water use rates of orchard trees in California. A water use rate of 6 acre-feet per year is estimated to be a reasonable figure. The agroforestry demonstration program has initiated a study of relative humidities of the air mass as it moves into, across and out of eucalyptus plantations. This can be used to further refine estimates of actual water use under plantation conditions in California.

Since exact water use in San Joaquin Valley conditions is approximate, some basic assumptions were used in the design of plantation/evaporation pond alternative. Using a general rule of one acre of trees for every ten acres of crop, a plantation size of 15 acres for a 160 acre field was selected for design and economic analysis. This is little larger than needed for a typical operation if water use if the only design consideration. This over sizing allows for low water use during the establishment period and immediately following tree harvests. The regulating reservoirs and/or evaporation ponds were then designed to accommodate the maximum quantities of drain water expected during a normal year. In areas of high drainage yield due to regional flows, the plantation size was increased to 20 acres when the engineering design did not include a regulating reservoir. Even at this size there would be some back-up and flooding of the plantation during the winter rainfall period when tree water use is low. In the case of very efficient crop irrigation with no regional flow problems, a plantation size of less then 10 acres would be more appropriate to use for system design. The intent of this study is to illustrate various ways that trees can be used with existing water disposal approaches and to compare the relative economics of these combinations. For this purpose, tree plantation sizes were chosen for moderate to high drainage yields. Design changes would be appropriate for very low or very high drainage yield situations.

How eucalyptus will tap into and utilize ground water will depend upon the nature of the soils involved and how the water moves through them. On heavy soils with little lateral movement of water, the effect will only be apparent within or near the plantation. On sandy soils with more rapid lateral movement of ground water, the effect will be more noticeable. Since most planned evaporation ponds are located on heavy soils, the use of eucalyptus to manage nearby ground water is probably infeasible and drainage installation will still be necessary. Planting eucalyptus on the sandier soils upslope will intercept most of the lateral flow into downslope areas. Even on the sandier soils the lateral movement of water through the soil is uneven and relatively slow, so the effects may not be apparent downslope for years. At any rate, the water table should lower within plantations and allow the planted trees to better utilize the site as time progresses. The best estimates presently available indicate that eucalyptus will transpire about 90 percent of open water evaporation rates where water uptake and use is limited by dissolved solids in the ground water. This means that once the

plantation is established and the site occupied (2 to 3 years, depending upon management), the trees will use about 6 acre-feet of water per year. This study assumes a slightly oversize tree planatation in order to take advantage of the potential of the trees to tap into and utilize the ground water. This ability to utilize ground water is an important consideration when determining underground drainage spacing. It is probably prudent to begin with a wide drain pipe spacing and make any needed adjustments around the outside edge. Close drain pipe spacing increases the likelihood that tree roots will invade and block the pipe. A forester familiar with eucalyptus and casurina believes that a 10-foot spacing is adequate. This estimate is based on observations of drainage installed in orchards. An engineer believes the drain spacing should be a minimum of 1.5 times the mature canopy radius.

How the dissolved solids content of the ground water affects water uptake is presently unknown. Water uptake is affected by the actual mix of the dissolved solids in the ground water. Estimated rates were based on studies which only included some of the salts or elements known to be in the ground water in the area. It is beyond the scope of this study to predict how the ground water will change over time. If some water uptake problems develop during the life of the plantation, it may become necessary to occasionally irrigate with fresh water and flush salts into installed drainage as previously described. The agroforestry demonstration project will monitor the ground water in the planted areas and include the information in the final report.

The net present value (NPV) analysis assumed that inflation will act about equally over the long run on all items. Some experts expect that energy related or energy convertible items may increase in value faster then the general inflation rate. Since opinions do vary, the NPV analysis for biomass included a very high value ($50/bone dry ton) for chips to display the effect of expected future energy price increases, and the computer analysis in Appendix A assumes a real price increase for firewood of 0.5 percent per year.

In view of the uncertainty of present knowledge discussed above, it is important to realize the limitations of this study. The focus was on the individual field where the potential environmental problems would be minimized. Woodlots were used to reduce the amount of water which would need to be managed and not for disposal of drain water. The selection of an off-site disposal area was on a geologic formation without restrictive clay layers, where deep percolation of water would not be a problem. The underlying aquifer was also heavily saline and not usable for domestic or irrigation purposes, so that groundwater contamination was not a consideration. Other approaches would have to be used elsewhere. The EIR's/EIS's published by the Westlands Water District and the USDI-Bureau of Reclamation document this very well. To evaluate the role or best use of woodlots for centralized drain water disposal under those

conditions would require the collection and evaluation of considerable additional environmental and site specific data.

The analysis assumes that all land in the study area which needs to be drained will be drained. If this is not the case, those landowners with installed drainage will have much higher drainage yields because of lateral movement from fields upslope. The analysis indicates that a collective or project-type approach is needed to uniformly address the problem. There are efficiencies in a collective approach which could well justify an area-wide drainage project.

As mentioned previously, the economic evaluation used only those markets and equipment presently available in the area. Since some market improvement or equipment development is likely in the next 20 years, this may tend to make the analysis conservative.

APPENDIX A. Agroforestry

SPECIES SELECTION AND RECOMMENDATIONS

The following criteria were used to select species for this study:

- Tolerance of saline soil and water.
- Cold tolerance to at least 20° F (-21° C) and heat tolerance to at least 104° F (40° C).
- High water using potential and waterlogging tolerance.
- Low attractiveness as a domestic animal or wildlife food source (to minimize problems of bioaccumulation of selenium and boron).
- Reported success in other parts of the world under similar conditions to the study area.
- Planting stock or reproduction technology available.
- Produces high tonnage of biomass under expected conditions.
- Minimal chance of escape to become a weed problem.
- Few pest or disease problems under recommended management.
- Uptakes potentially harmful elements at low levels or in biologically inactive form.

These criteria lead to two kinds of trees for intensive consideration, Eucalyptus and Casuarina.

Some close choices that were eliminated are:

- Poplars because of limited salt tolerance.
- Tamarix due to limited available markets and high potential for some species to escape cultivation and become weed problems. This limits farmer acceptance.
- Mesquites due to limited markets and high attractiveness to wildlife and domestic animals for forage.
- Pines (P. eldarica and P. brutia) due to low tolerance for heavy, waterlogged soils.
- Guayle and Jojoba because markets are presently limited, and low water use potential.
- Sesame and sunflower due to waterlogging sensitivity.

- Grasses and shrubs because of relatively low water transpiration ability when compared to trees. Selected grasses and shrubs can probably be used for extraction of some dissolved solids when planted along with trees (e.g, Allenrolfea occidentalis and Atriplex).

Of the trees judged most useful, the species with the widest success elsewhere is river red gum (Eucalyptus camaldulensis). This species has several provenances selected from throughout Australia which tolerate saline soil conditions like those found in the study area and produce a wood crop suitable for pulp, firewood, or biomass. Two species of Casuarina which also have potential are C. glauca and C. cunninghamiana. These have slightly lower growth rates than eucalyptus and are of unknown usefulness as a pulp species, but are more windfirm and some provenances are very salt tolerant. They may also fix nitrogen in root nodules and should be considered as a species for mixing with the eucalyptus.

At least two ongoing trials indicate that Eucalyptus trabutii can outgrow river red gum under some conditions in California and should be considered a possible mix species on better sites. This hybrid species has not been tested for adaptability to the combination of waterlogging and salt, so extensive planting is not recommended.

CULTURAL RECOMMENDATIONS

Pre-planting site preparation, including weed control, is the same as presently used for many crops being grown. Eucalyptus seedlings are generally supplied in vegetable trays and can be planted using a tree seedling transplanter like the Whitfield Model #57-S or equivalent. Transplanting beds have been successfully prepared using a tomato lister with every other bed plowed for furrows. The furrows should be plowed wide and deep enough to be used over a period of years. Furrow width and depth should allow for natural sloughing, sediment collection, and weathering. This allows a spacing of about 6 feet by 6 feet or 5 feet by 7 feet, for a stocking of a little over 1,200 trees per acre.

A pre-irrigation with fresh water is recommended. Fresh water should be used for establishment during the initial growing season with a total of about 1.5 acre-feet of water applied by sprinklers, as the site allows. Recycled drain water can be used for furrow irrigation thereafter, although it should not exceed 12,000 ppm TDS, for best results. Normally about six irrigations per season are needed, depending on site conditions. Total application rates can be increased from an estimated 2 acre-feet during the second growing season up to an optimum of 5 or 6 acre-feet during the fifth growing season in as many applications as the soil type will accept. Existing saline conditions in the ground water will probably limit water uptake and use in most areas to a maximum of 6 acre-feet. In other areas where the tree

water use and uptake is not limited by high water tables or salinity, it should approximate evaporation from an open pan.

Weed control is essential for at least the first year, therefore a pre-emergent herbicide is recommended as part of the site preparation. Additionally, weed control by chemical, mechanical, or manual means may be needed until the trees start to fully occupy the site after the second growing season. Good weed control not only reduces unwanted competition with the trees, but also reduces fire hazard and attractive cover for potentially damaging animals like rabbits, gophers and mice.

A stocking level of approximately 1,200 trees per acre is recommended for several reasons. The older established eucalyptus plantations in California are generally at a spacing of 8 feet by 8 feet (680 trees/ac.) or 10 feet by 10 feet (435 trees/ac). These plantations received little or no cultural care aside from some irrigation for establishment after planting. More intensive culture and shorter rotations indicate closer spacing is needed to best utilize the land. One thousand trees per acre (7'x 7' triangular) is commonly recommended, but since river red gum tends to be very poor form (weeping willow, corkscrew shaped, or forked tops) unless a little crowded, a dense stocking is better. Also, until the site is fully occupied, the denser the stocking, the higher the resulting water use.

Field visits to some eucalyptus plantations of various densities in California reveal that, at closer than 5-foot by 5-foot spacing (1,740 tree/ac), the number of dead or severely suppressed trees increases noticeably after the tree canopy closes. This can sometimes be overcome on the best sites by intense weed control, irrigation, and fertilization practices. This field observation is supported by the U.C. Cooperative Extension Service's Eucalyptus Growth and Yield Model which normally determines a stocking level of 1,200 trees per acre to be best for maximum fiber yield. Spacing at closer than 6 feet by 6 feet also makes access with most harvest equipment very difficult. Lastly, most of the plantations will be managed by coppice or resprouting systems. This means that for every seedling initially planted, there will be an average of about three trees per stump after the first harvest. An initial stocking of 1,000 trees per acre, with a 90 percent stump resprouting rate, will actually be about 2,500 trees per acre over most of the plantation's life.

The relatively poor form of river red gum can be a problem in plantations to be chipped for pulpwood or cut into firewood. Straight standing stems with small lateral branches have a higher stemwood yield for firewood or pulp quality chips. Pruning young trees will usually encourage better form. Another way to help get better form is to plant several rows of Casuarina glauca or C. cunninghamiana around the outside of the plantation and every 5 to 10 rows within the plantation. The casuarina are much more windfirm and upright than the eucalyptus and help improve the

growth habit of the red gum. Recent research in Hawaii indicates that a nitrogen fixing species can be planted in a eucalyptus stand without reducing the yield of the eucalyptus very much. Since casuarinas have root nodules which apparently fix nitrogen, their use in the plantation is recommended. This species mix should also provide some protection against the spread of diseases through natural root grafts.

Plantation layout should have needed access included. In large plantations, 20 feet of every 200 feet parallel to the irrigation furrows should be used for management access or plantation protection and left unplanted. This gives some protection against fire, disease, and insects by separating the plantation into units. Access by larger harvesting equipment is easier, and the open area can be used to stack the cut trees for some air drying prior to chipping or hauling. If water table depth or salt build-up in the soil are problems, the open strip will allow the installation of subsurface drainage so that the salts in the soil profile can be managed. In areas with installed drainage, the access strip should coincide with the drain to provide some separation from the trees and their root systems. This should minimize root clogging of the drainage pipe. In those plantations with installed drainage, the spacing between the drains should be about twice that normally required. This allows the trees to better use the applied water and for the tolerance of river red gum to waterlogging.

For ease of water collection, the plantation should be on the lowest side of the field or used as a windbreak, whichever is appropriate. In the study area, an east-west orientation along the north side of the field would generally allow both easy collection and use of drain water and effective windbreak protection. Plantings to intercept subsurface water have been successfully done in Australia, although the results may take decades to become evident depending on the soils involved. The limiting factor for subsurface interception is the relatively slow lateral movement of water in heavy soils. On sandier soils, strips of trees can be used to tap into and intercept subsurface water flowing downslope into adjacent fields. This can, over a period of years, reduce water table problems.

PLANTATION MANAGEMENT AND HARVEST

The recommended species can be "coppiced managed". This means the individual trees will coppice, i.e. resprout after they are cut, and do not need to be replanted after each harvest. Coppice management usually requires that a one-foot high stump be left in a relatively undamaged condition. Sufficient sunlight must normally be allowed to reach the stumps to stimulate the sprouting and allow them to grow rapidly enough to re-establish the plantation (especially to outgrow weeds). The recommended species will prolifically resprout when clear-cut in California. It is best to pick out two to three of the sprouts and prune the rest. This allows the tree to concentrate growth on selected sprouts and makes the next harvest much easier. The regrowth of

the plantation is rapid and only requires about 70 to 80 percent of the initial rotation to reach harvest size again. In California, the individual trees of the coppice rotation are taller and straighter than the initial plantation, and are better suited for pulpwood or cordwood than the initial harvest. Coppice management can be continued until the stumps become too big and branched for mechanical harvest or until failure to resprout (normally 5 to 10 percent each time) leaves holes in the plantation, which lowers growth and yield.

Plantation management will vary depending upon intended products and how the plantation fits with other farm operations. One of the primary concerns is the timing between harvests. Some farmers may want to harvest as soon as possible. Minimum age harvests would be with biomass fuel for power generation. This could be at age 5 years. Harvest at shorter rotations would significantly reduce water consumption; and, since one objective is to use recycled drain water from adjacent croplands, a shorter harvest cycle was not considered. The U.C. Cooperative Extension Growth and Yield Model indicates that average annual growth will peak at about 10 years of age, so this was used as a maximum. This gives a harvest cycle of between 5 to 10 years, depending upon product and management objectives. For analysis purposes, a 5-year rotation was used for biomass management. A longer rotation was used for firewood of 6 years from planting, and 6 years for the regrowth harvests. These rotations will produce an average chest-high diameter of approximately 5 to 6 inches, which is about the smallest size desirable for firewood harvest. A longer rotation was used for pulpwood, where a larger tree size is desirable for better pulp quality chip yield. The U.C. Cooperative Extension Growth and Yield Model printout is included in Appendix A to give examples of possible plantation management schemes for comparison purposes.

A range of yields was also used for analysis. The demonstration plantings indicate that the medium site option of Site Index 85 (i.e., the tallest trees will be 85 feet high at 10 years of age) should be used for the computer analysis. A yield of 5 cords per acre per year or 10 tons per acre per year is commonly accepted to represent intensively managed eucalyptus plantations in California and was used as a base level. This was reduced by 33 percent to 3.5 cords/acre/year or 7 tons/acre/year to reflect expected growth reductions, due to the saline water, for average yield analysis.

Each individual site will need to be monitored, along with the existing market conditions, for the best age at which to harvest. The range in suitable harvest ages will allow some selection of the best market for a particular farm's management needs. The longer rotations will be best if water use and the production of firewood or pulpwood is the goal. If quick cash flow is needed, shorter rotations are best where maximum water use is not as important and the intended market is biomass fuel. The Eucalyptus long-horned borer can also be managed with these coppice lengths, should it become a problem in the area.

Frequent harvest scheduling will allow any borer infestation to be cut and chipped for biomass fuel, thus killing the larvae.

The economic analysis used existing farming equipment wherever possible. Where farm equipment could not be substituted, only equipment presently available and used in California was selected. Where a particular manufacturer is mentioned the intent is not exclusive endorsement, but to specifically describe the type of equipment used in the analysis. It was also assumed that existing farm labor would be used if possible, even if there was some cost-effective equipment available. This would allow the individual farms to better utilize their year-round employees. For this reason, a labor-intensive cutting and stacking system was used for firewood. A mechanized total tree harvest and chipping system was used for biomass with a chip cleaner/separator added for pulp chips. The weather, terrain, and uniform tree size will allow optimum use of mechanized harvest equipment. No adjustment to the manufacturer's published production information was deemed necessary. Morbark tree harvesting equipment was used as the basis for the analysis because of its suitability for the conditions and readily available dealership. It was assumed that the acreages planted would be large enough to justify the purchase of a Morbark Model 20 Total Chip Harvester and required support equipment by some local individuals or company. Depending upon support equipment, this system will harvest between 175,000 to 250,000 tons per year with an expected equipment life of five years. This equals the annual growth on about 25,000 acres of plantation with a maximum of 3,000 to 4,000 acres of plantation being harvested in any one year.

Tree cutting can be done by a feller/buncher in advance of the chipping and hauling. The bunches of felled trees can be skidded and stored on access areas to partially air dry. The whole trees should be down to an acceptable 40 percent moisture content (wet basis) within about 30 days during drier weather. The trees can then be chipped and loaded directly into chip vans for hauling to market. It is estimated that 100 percent of the biomass yield will be useable for boiler fuel, but only 75 percent of the yield will be suitable for pulp chips and the remaining 25 percent for boiler fuel. Pulp chip yield will be reduced to approximately 50 percent for mills which manufacture high quality print paper and need bark free chips. Felling/bunching in advance of chipping/ hauling will also allow tree harvest during periods of high resprouting potential by avoiding harvest during periods of very high or very low temperatures. Field observations at U.C. Davis indicate that resprouting after harvest with a snipping type feller/buncher will not be a problem.

The trees can be machine harvested for firewood at a lower cost in the long run than by using labor; but, as explained earlier, the trees can also be cut by chain saw, tractor skidded to the access area, then bucked into suitable lengths and stacked by hand for air drying. Depending upon the buyer, the air drying period may be as long as one year. The wood can be boxed or

stacked on pallets for hauling to either the San Francisco Bay area or the Los Angeles metropolitan area (since the study area is approximately midway between these two large firewood markets). The economic analysis assumes that the firewood will be marketed as cordwood lots; however, there appears to be an ever-increasing demand in boxed firewood for immediate use. This market will allow higher profit, but is probably sensitive to competition so it was not included in this analysis. Some authorities predict that boxed firewood demand is expanding and is the market of the future. Eucalyptus plantations will produce a quality, uniform product which can be easily boxed for this market.

UNIVERSITY OF CALIFORNIA COOPERATIVE EXTENSION

EUCALYPTUS GROWTH AND YIELD MODEL

COMPUTER PRINTOUTS

Rinehart/Standiford Growth and Yield Model

General background for this study was provided by a eucalyptus growth and yield computer model, which included financial analysis based on average costs for California. This linear regression computer model was developed by J.A. Rinehart and R.B. Standiford for firewood using data from a study of Eucalyptus globulus stands throughout California by W. Metcalf in 1924. These stands were generally irrigated for establishment only and received minimal care thereafter. To use this model for Eucalyptus camaldulensis in intensively managed stands on salt and water table affected sites required some adjustment of normal input values. The basic assumption was that since Eucalyptus globulus grew fairly well on those sites where it survived. The yield model developed from that data would approximate intensive management in the study area.

The medium site (10-year tree height of 85 feet or Site Index 85) represents the potential growth and yield that can be reasonably attained in the westside vicinity. This site index was calculated from the tallest trees of the demonstration plantations in the study area (i.e., 12 feet at 1-1/2 years). The first coppice harvest timing was adjusted to 80 percent of the seedling harvest age because a slightly slower than normal coppice growth rate was anticipated due to poor water quality. Irrigation cost was adjusted from a series of costs over the plantation life to a present value to fit the model. Other cost adjustments from the average values were based on the specific cost information. The model provides economic analysis for firewood production only, and printouts using various cordwood stumpage values and land rents follow. These estimates are probably the best that can be expected for those areas with salinity or water table problems in the west side of the San Joaquin Valley.

INPUT VALUES

$40 Stumpage/$120 Land Rent

Site Index = 85

Stocking = 1200 trees per acre

Rotation Length = 5 to 15 years

Stump Survival Rate = 95%

Coppice (Cop) = 80% of seedling rotation length (Seed)

Minimum Average Stand Diameter (ASD) = 5 inches

Stumpage Price = $40.00 per cord (selling price less haul & harvest)

Site Preparation = $78.50 per acre

Weed Control = $44.00 per acre per year for first two years

Seedling Cost = $0.20 per seedling

Planting Cost = $0.045 per seedling

Irrigation Cost = $289.00 per acre

Administration Costs = $4.00 per acre per year

Land Rent = $120.00 per acre per year

YIELD TABLE

SITE = 85 STOCKING = 1200

AGE	ASD	BA/ac	Y-ft^3	Y-cd	MAI-ft^3	MAI-cd
5	4.3	82	1670	19	333.9	3.7
6	4.8	102	2363	26	393.8	4.4
7	5.2	119	3028	34	432.5	4.8
8	5.5	134	3647	41	455.8	5.1
9	5.8	146	4214	47	468.2	5.2
10	6.0	158	4731	53	473.1	5.3
11	6.2	167	5201	58	472.8	5.3
12	6.3	176	5628	63	469.0	5.2
13	6.4	183	6017	67	462.8	5.1
14	6.6	190	6371	71	455.1	5.1
15	6.7	196	6695	74	446.4	5.0

VARIABLE MANAGEMENT ANALYSIS

SITE = 85 STOCKING = 1200

AGE			YIELD (Cords)					
SEEDLING	COPPICE	ASD	ROT1	ROT2	ROT3	ROT4	RRI	9% PNW
5	4	4.30	19	18	18	18	%-.010	-354
6	5	4.80	26	26	25	25	.100	111
7	6	5.19	34	33	32	32	0.117	388
8	6	5.50	41	40	39	38	0.135	817
9	7	5.76	47	46	45	44	.130	795
10	8	5.97	53	52	51	50	0.124	735
11	9	6.15	58	57	56	55	0.117	620
12	10	6.31	63	61	60	59	0.108	417
13	10	6.44	67	66	65	63	0.107	438
14	11	6.56	71	70	68	67	0.098	219
15	12	6.66	74	73	72	71	0.091	24

GUIDE TO ABBREVIATIONS:

ASD Average Stand Diameter at 4.5 feet high.

BA/ac Basal Area: the cross sectional area of the stem at 4.5 feet high. This is highly correlated to volume growth and is a convenient way to measure true stocking levels.

Y-ft^3 Yield in cubic feet of solid wood. Depending upon the diameter of the wood, there is 85 to 90 cubic feet in a cord.

Y-cd Yield in cords. One cord is a stack of wood 4 ft. x 4 ft. x 8 ft

MAI Mean Annual Increment--a measure of growth rate.

ROT Rotation: The first rotation is the seedling harvest and the second to fourth are coppice harvests.

INPUT VALUES

$40 Stumpage/$40 Land Rent

Site Index = 85

Stocking = 1200 trees per acre

Rotation Length = 5 to 15 years

Stump Survival Rate = 95%

Coppice (Cop) = 80% of seedling rotation length (Seed)

Minimum Average Stand Diameter (ASD) = 5 inches

Stumpage Price = $40.00 per cord (selling price less haul & harvest)

Site Preparation = $78.50 per acre

Weed Control = $44.00 per acre per year for first two years

Seedling Cost = $0.20 per seedling

Planting Cost = $0.045 per seedling

Irrigation Cost = $289.00 per acre

Administration Costs = $4.00 per acre per year

Land Rent = $40.00 per acre per year

YIELD TABLE

SITE = 85 STOCKING = 1200

AGE	ASD	BA/ac	Y-ft^3	Y-cd	MAI-ft^3	MAI-cd
5	4.3	82	1670	19	333.9	3.7
6	4.8	102	2363	26	393.8	4.4
7	5.2	119	3028	34	432.5	4.8
8	5.5	134	3647	41	455.8	5.1
9	5.8	146	4214	47	468.2	5.2
10	6.0	158	4731	53	473.1	5.3
11	6.2	167	5201	58	472.8	5.3
12	6.3	176	5628	63	469.0	5.2
13	6.4	183	6017	67	462.8	5.1
14	6.6	190	6371	71	455.1	5.1
15	6.7	196	6695	74	446.4	5.0

VARIABLE MANAGEMENT ANALYSIS

SITE = 85 STOCKING = 1200

AGE			YIELD (Cords)					
SEEDLING	COPPICE	ASD	ROT1	ROT2	ROT3	ROT4	RRI	9% PNW
5	4	4.30	19	18	18	18	0.172	881
6	5	4.80	26	26	25	25	0.188	1345
7	6	5.19	34	33	32	32	0.192	1623
8	6	5.50	41	40	39	38	0.199	2052
9	7	5.76	47	46	45	44	0.190	2029
10	8	5.97	53	52	51	50	0.180	1970
11	9	6.15	58	57	56	55	0.171	1855
12	10	6.31	63	61	60	59	0.160	1651
13	10	6.44	67	66	65	63	0.156	1673
14	11	6.56	71	70	68	67	0.146	1453
15	12	6.66	74	73	72	71	0.138	1258

GUIDE TO ABBREVIATIONS:

ASD Average Stand Diameter at 4.5 feet high.

BA/ac Basal Area: the cross sectional area of the stem at 4.5 feet high. This is highly correlated to volume growth and is a convenient way to measure true stocking levels.

$Y\text{-}ft^3$ Yield in cubic feet of solid wood. Depending upon the diameter of the wood, there is 85 to 90 cubic feet in a cord.

Y-cd Yield in cords. One cord is a stack of wood 4 ft. x 4 ft. x 8 ft

MAI Mean Annual Increment--a measure of growth rate.

ROT Rotation: The first rotation is the seedling harvest and the second to fourth are coppice harvests.

INPUT VALUES

$35 Stumpage/$40 Land Rent

Site Index = 85

Stocking = 1200 trees per acre

Rotation Length = 5 to 15 years

Stump Survival Rate = 95%

Coppice (Cop) = 80% of seedling rotation length (Seed)

Minimum Average Stand Diameter (ASD) = 5 inches

Stumpage Price = $35.00 per cord (selling price less haul & harvest)

Site Preparation = $78.50 per acre

Weed Control = $44.00 per acre per year for first two years

Seedling Cost = $0.20 per seedling

Planting Cost = $0.045 per seedling

Irrigation Cost = $289.00 per acre

Administration Costs = $4.00 per acre per year

Land Rent = $40.00 per acre per year

YIELD TABLE

SITE = 85 STOCKING = 1200

AGE	ASD	BA/ac	Y-ft^3	Y-cd	MAI-ft^3	MAI-cd
5	4.3	82	1670	19	333.9	3.7
6	4.8	102	2363	26	393.8	4.4
7	5.2	119	3028	34	432.5	4.8
8	5.5	134	3647	41	455.8	5.1
9	5.8	146	4214	47	468.2	5.2
10	6.0	158	4731	53	473.1	5.3
11	6.2	167	5201	58	472.8	5.3
12	6.3	176	5628	63	469.0	5.2
13	6.4	183	6017	67	462.8	5.1
14	6.6	190	6371	71	455.1	5.1
15	6.7	196	6695	74	446.4	5.0

VARIABLE MANAGEMENT ANALYSIS

SITE = 85 STOCKING = 1200

AGE			YIELD (Cords)					9%
SEEDLING	COPPICE	ASD	ROT1	ROT2	ROT3	ROT4	RRI	PNW
5	4	4.30	19	18	18	18	0.147	569
6	5	4.80	26	26	25	25	0.166	974
7	6	5.19	34	33	32	32	0.172	1222
8	6	5.50	41	40	39	38	0.182	1631
9	7	5.76	47	46	45	44	0.173	1589
10	8	5.97	53	52	51	50	0.166	1556
11	9	6.15	58	57	56	55	0.157	1436
12	10	6.31	63	61	60	59	0.148	1269
13	10	6.44	67	66	65	63	0.144	1274
14	11	6.56	71	70	68	67	0.136	1102
15	12	6.66	74	73	72	71	0.128	920

GUIDE TO ABBREVIATIONS:

ASD Average Stand Diameter at 4.5 feet high.

BA/ac Basal Area: the cross sectional area of the stem at 4.5 feet high. This is highly correlated to volume growth and is a convenient way to measure true stocking levels.

Y-ft^3 Yield in cubic feet of solid wood. Depending upon the diameter of the wood, there is 85 to 90 cubic feet in a cord.

Y-cd Yield in cords. One cord is a stack of wood 4 ft. x 4 ft. x 8 ft

MAI Mean Annual Increment--a measure of growth rate.

ROT Rotation: The first rotation is the seedling harvest and the second to fourth are coppice harvests.

APPENDIX B. Soils

The following soils descriptions represented by the Little Panoche Creek Soil and Landscape Profile (Figure B on page 3) is representative of the types of soils and landscapes found in the study area. More detailed soils information may be obtained from the Soil Conservation Service's Hanford Soil Survey Office. Soils described in this section are part of the ongoing Soil Survey, Fresno County, California, Western Part and are subject to revision.

Soils in the lower portion of the watershed between the San Joaquin River and the San Luis Drain (Figure B) are used primarily for wildlife habitat, recreation, and growing saline-sodic tolerant irrigated field and row crops. The three representative soils are Columbia, Tachi, and Lillis. High salinity and sodicity is a naturally occurring problem for the Lillis and Tachi soils.

The Columbia soils are very deep. A typical profile has a pH of 6.1 to 7.8, no salinity and consists of 16 inches of fine sandy loam underlain by 39 inches of stratified fine sandy loam, sand, silt loam and loam. A seasonally high water table at a depth of 4 to 6 feet usually occurs between December and March.

The Tachi soil is deep and alkali affected. Electrical conductivity (EC) is greater than 8 mS/cm. A typical profile has a 22-inch surface clay layer with a pH of 6.6 to 8.4, and is underlain by lighter colored clay to a depth of 60 inches with a pH of 7.8. Tachi soil has a perched water table at a depth of 4 to 6 feet.

The Lillis soil is very deep, poorly drained and saline-sodic throughout its profile. Typically the clay-textured surface layer is 13 inches thick. The underlying material, to a depth of 60 inches, is also clay and is calcareous throughout. Permeability is very slow. Effective rooting depth of crops is limited by a perched water table at a depth of 4 to 6 feet.

Panoche and Excelsior soils are representative between the San Luis Drain and the California Aqueduct (See Figure B) and are used primarily for growing irrigated saline-sodic tolerant field and row crops such as cotton, alfalfa, tomatoes and corn. Salinity and sodicity are minor problems.

The Panoche soils are deep and well drained, formed in calcareous alluvium from sedimentary formations on alluvial fans. Salinity is moderate and the natural water table is generally deeper than 6 feet. The surface loam-textured layer is underlain by calcareous heavy loam to a depth of 24 inches. The subsoil, to a depth of 60 inches, is a dark calcareous clayloam. Slopes are 0 to 2 percent.

The Excelsior soils are deep, moderately well-drained soils formed in alluvium from igneous and sedimentary rocks. Excelsior soils are on the portions of alluvial fans west of the Panoche soils and slopes are 0 to 2 percent. Excelsior soils in this area are also used primarily for growing saline-sodic tolerant irrigated field and row crops. Typically, the surface is sandy loam 8 inches thick and saline-alkali in some parts of the profile (EC is greater than 8 mS/cm). The water table is below 6 feet.

In the area between the California Aqueduct and Interstate 5, the predominant soils are Cerini and Milham which are used for growing field and row crops such as cotton, barley, wheat, alfalfa, tomatoes, onions, garlic, and cantaloupes. Almonds are also grown in some areas. Soil salinity is low (EC less than 2 mS/cm) and the water table is below 5 feet.

The Cerini soils are deep, well drained soils that have formed in alluvium derived primarily from sedimentary rock. Cerini soils are on alluvial fans and terraces. Cerini soil is neutral to moderately alkaline. Saline-sodic phases are recognized. The surface layer is light brownish gray clay loam about 25 inches thick. Permeability is slow. The upper 10 inches of underlying material is light gray silt loam. The lower part to a depth of 62 inches is stratified light brownish gray and light gray sandy loam and loam. The soil is calcareous throughout. Lateral subterranean movement of irrigation water from higher adjacent areas can create a perched water table above a denser layer.

The Milham soils are well drained and occur on old alluvial fans. They are formed mainly from granitic rock sources. Typically, the surface layer is 10 inches thick and consists of sandy loams, fine sandy loams and loams. The subsoil is yellowish brown clay loam underlain at about 49 inches by a light brown and very pale brown sandy loam to 60 inches.

Above I-5 the Polvadero and Belgarra soils occur on the areas where fan alluvium and slope alluvium steepen (see Figure B).

The Polvadero soils are very deep, well drained and sodic. Permeability is slow formed in alluvium from sedimentary rock. Polvadero soils occur on fan terraces and the upper part of alluvial fans where slopes range from 0 to 15 percent. Elevations rise above the valley floor from 400 to 1,000 feet. These soils are used as rangeland for livestock grazing, wildlife habitat, and for growing irrigated crops such as cotton and grain. Natural vegetation is mainly red brome, foxtail fescue, filaree and salt bush. Salinity is low (1.0 mm Hos/cm). Use as irrigated cropland is limited by steepness in certain areas. The upper 12 inches of the soils profile is light yellowish brown sandy loam underlain by a light yellowish brown sandy clay loam to 30 inches. From 30 to 52 inches the soil is sandy clay loam, and sand loam from 52 to 60 inches. The profile is moderately to strongly alkaline (PH 8.4 to PH 9.0).

The Belgarra soils are well drained and have high concentrations of gypsum in the subsoil. They have formed from weathered shale at elevations of 1,000 to 2,000 feet on slopes from 8 to 30 percent. The soils support rangeland and wildlife habitat and are used mainly for livestock grazing. Native grasses utilized for grazing are soft chess, red brome, filaree, foxtail fescue, Mediterranean barley and ripgut brome. Average grass production is 2,800 lbs/acre-dry weight. Salinity averages from 2 mm Hos/cm at the surface to 8 mm Hos/cm at 6 feet. The water table is below 6 feet. A typical profile has 10 inches of grayish brown clay underlain by 35 inches of grayish brown clay with high gypsum content. The substratum to 72 inches is light yellowish brown clay.

The Exclose soils are on back slopes of foothills and have slopes of 30 to 65 percent. Elevations range from 1,000 to 3,240 feet (see Figure B). These soils have been formed in material weathered from shales of the Kreyenhagen formation. These soils are well drained, runoff is rapid and permeability is moderately slow. These soils are moderately alkaline with a profile of 12 inches of clay loam and sandy loam underlain by sandy clay loams to 84 inches. These soils are used as annual rangeland and wildlife habitat. The vegetation is soft chess, red brome, ripgut annual grasses and forbs, with scattered shrubs.

The Exclose soils transcend into the Badlands which are nearly void of vegetation (less than 10 percent plant cover) with slopes of 30 to 65 percent. The Badland soil is a very shallow and well drained, gravelly sandy loam, and 2 to 6 inches deep over highly fractured shale.

APPENDIX C. Economic Evaluations

INTRODUCTION

This appendix contains two parts. First is a calculation of the economic implications of eucalyptus plantations under two different conditions. These are:

- Feasibility of eucalyptus planted in areas with a high water table to produce an economic crop and intercept ground water flow. This system uses no drain water, although some irrigation is required for establishment. In the following evaluation, this is called the low input system.

- Feasibility of eucalyptus to produce an economic crop utilizing saline agricultural drain water to irrigate the woodlot after establishment. In the evaluation, this is called the average input system.

Part two of this appendix builds upon the evaluation of the average input system discussed above. The net present value of eucalyptus plantations under several different scenarios was determined in part one. This was used, along with information on the net present value of agricultural crops, as part of a more comprehensive evaluation of the feasibility of various systems of disposing of agricultural drain water. The drain water disposal systems evaluated are:

- Evaporation Pond Only (lined and unlined)
- Evaporation Pond (lined and unlined) with Eucalyptus Plantation
- Evaporation Pond (lined and unlined) with Regulating Reservoir/Tailwater Pond and Eucalyptus Plantation

The results of this analysis are shown in Figure C-4. It should be remembered that this evaluation pertains to lands where leaching and drainage are necessary for crop production and the necessary field drainage lines are installed. These lands used to have their drainage effluent pumped into the San Luis Drainage Canal. Since the plugging of the San Luis Drain, this drainage water has been blended with fresh irrigation water and reapplied to the crops. This will eventually destroy the productive capacity of the land.

At present, it is not known exactly how long the recycling of agricultural drain water can continue before yields are reduced to the point where the land can no longer be profitably farmed. However, the growers know they are gradually salinizing their soils and are actively seeking other ways to dispose of their drain water.

This evaluation <u>will not</u> try to determine the rate of soil degradation and economic loss. This evaluation <u>will</u> focus on

comparing the costs and returns of the various ways of disposing of agricultural drain water.

ECONOMIC FEASIBILITY OF EUCALYPTUS PLANTATIONS

The SCS has developed an electronic program to evaluate the financial feasibility of Eucalyptus plantations. Cost information was gathered during interviews with typical growers and price information was obtained from potential buyers in or near the study area.

The concept of Eucalyptus plantations as an agricultural enterprise is new to California. The industry is just now developing its production systems, and the structure of the marketing system is still unclear. For these reasons, many different combinations were run through the SCS evaluation program.

Growers and other interested individuals can choose the one that best fits their resource and financial conditions and their expectations about future marketing opportunities. Following is a description of the variable elements of the analysis:

- Expected Yield

  The yield estimates used to generate plantation incomes were developed by comparing height and diameter measurements from the demonstration plantations to those of eucalyptus plantations on sites not affected by salt or water table problems (Navelencia and Yolo County). Using this approach, average yield of firewood was estimated at 3.5 cords per acre per year, or 7 dry tons of biomass per acre per year (75 percent pulpwood chip yield). These estimates represent the average yields which can be expected from the study area. A second set of calculations was done using yield figures of 5 cords/acre/year or 10 tons/acre/year to give an idea of the best reasonably attainable returns for the area.

- Price

  Two market values were used to get an idea of how normal price fluctuations can affect returns.

- Market Choice

  Four basic market outlets for wood fiber from the San Joaquin Valley were identified. The markets are export of chips from Stockton deepwater port, pulp chips for paper manufacturing in Antioch, firewood for the San Francisco/Los Angeles areas, and biomass for power generation at Mendota (facility being constructed). The international wood chip market is very competitive so chip prices (delivered) at Stockton and Antioch were similar and, since the haul was comparable, were analyzed as one market (i.e., pulp chips delivered to Antioch). Similarly, the San Francisco and Los Angeles areas

were also considered one market. Local firewood markets are also very active, but probably sensitive to over supply. It is important to note that only existing markets presently buying eucalyptus were analyzed. Emerging markets like industrial feedstock for conversion into fuels or chemicals are additional possibilities to consider as they develop.

The combined demand of these markets varies between 1,000,000 and 3,000,000 cords per year and is large enough that no depression of present prices from a moderate increase in supply is anticipated. Eucalyptus is slightly discounted for firewood compared to oak, and this will probably continue because it can be much more efficiently produced. Some inroads of eucalyptus into the oak firewood market are anticipated over time, since they have very similar burning characteristics. This could reduce the demand for oak firewood if large acreages of eucalyptus are planted.

- Production Costs

Two production cost scenarios were evaluated. The average cost scenario has a seedling cost twenty cents a tree and includes a charge for irrigation labor ($27.60/ac/yr) to handle the drain water used to irrigate the trees in the years after they are established. The low cost scenario has a seedling cost of ten cents per tree and no charge for irrigation labor after the establishment year. It must be remembered that the low cost scenario does not utilize drain water and therefore will not help dispose of drain water. It is an alternative to the current cropping system, not an adjunct.

- Land Rent

Land rent reflects the annual return to the land input in the production system. Land value is the capitalized value of future rents. Highly productive land has an annual land rent of about $120/acre. Land that has been salted out to the point it cannot produce a profitable crop, has an annual land rent of $0/acre. These two values for land rent (plus $40/acre) were evaluated.

- Interest Rate

The interest rate should reflect the price paid for the use of money. In this study, two rates were used. Eleven percent was used to reflect the current borrowing rate in the market place. Five percent was also used for comparison purposes to show how the rate influences economic feasibility.

Net present value, or NPV, is the sum that results when the current dollar value of the costs are subtracted from the current dollar value of the returns. If the NPV is a positive, then the enterprise is potentially worth undertaking. Rate of return on investment, or RRI, is

calculated by subtracting discounted costs from discounted returns and dividing that value by the discounted costs. Comparing this rate to the cost of capital provides a guideline as to whether a project could return a profit. When the RRI is greater than the cost of the money/capital, the project is economically justified.

With this many variables and this many different choices for each variable, there are 48 different scenarios for each market choice, as shown in Figures C-1 thru C-3. There are three market choices; therefore, a total of 144 options were considered in the SCS evaluation program.

ECONOMIC FEASIBILITY OF VARIOUS SYSTEMS OF DISPOSING OF AGRICULTURAL DRAINAGE

The previous section describes the analyses of eucalyptus plantations as a crop under numerous production and marketing combinations. Under several of these, eucalyptus plantations have a positive return.

This section will describe and compare three different systems for disposing of drain water from agricultural crops. All of the systems include evaporation ponds as the final disposal sink. Two of the systems include eucalyptus plantations. The plantations are intended to reduce the size of evaporation ponds by utilizing agricultural drain water that is too saline for crops, yet not too saline to serve as irrigation water for the eucalyptus trees while allowing the landowner some financial return. The plantations are sized to handle the expected drainage yield from the field crops, with some winter soil saturation for short periods during high rainfall.

It is important to note that each of the alternatives has different implications for the amount of land remaining in agricultural crop use. The annual net income per acre for the two predominant crops in the area is $216/acre for cotton and $17/acre for wheat.

The basic condition assumed for all three systems was for a field one-half mile long by one-half mile wide, encompassing 160 acres, with existing drainage, irrigation and tailwater return systems. Costs include only those components needed to add evaporation ponds and/or tree plantations to existing agricultural improvements. Pond sizing allowed for water in the subsoil from upslope and was based upon efficient irrigation practices with minimum leaching. Annual evaporation estimates were based on Hanford data adjusted for salinity increase and rainfall. No differences in salt management were included in the cost analysis. Costs were varied based upon high and low regional drainage yields.

Costs for fields larger than 160 acres can be lower due to efficiencies in installing levees, roads, drains and sumps. This reduction is estimated to be 5 percent in construction costs,

plus the gain of two acres of cropland for each 160 acres included in the base unit.

On some sites, due to soil conditions, the Regional Water Quality Control Board may require lining the evaporation pond. Bentonite and clay pond lining costs were estimated and included excavation, borrow and haul from suitable clay sites, five pounds of bentonite per square foot, mixing, wetting, compaction and trimming to grade. Construction costs may be lower if local clay borrow sites are available. Construction costs could be considerably higher if the ponds need to be sealed by double lining and the precipitated solids treated as Class I hazardous waste.

- System One - Evaporation Pond

  For a 160-acre field in an area with high regional drainage yield, it was estimated that a 25-acre evaporation pond, including land for levees and perimeter drains, would adequately evaporate the drain water. This would leave 135 acres available for field crops. The same field in an area with a low drainage yield would need a 9.9-acre pond and would have 150.1 acres available for field crops. Construction costs were based on averages for the Hanford area. Design includes storage for solids, with periodic cleaning being required. Figure D-1 in the engineering appendix shows a typical design for a 160-acre field with an evaporation pond.

- System Two - Evaporation Pond with Eucalyptus Plantation

  Crop drainage water would be used to irrigate tree plantations after establishment. The irrigation would be done with furrows. The plantations would have a separate drain system leading to the evaporation pond which would collect and evaporate the water leached through the plantation. The trees would not be planted closer than 10 feet to the drain pipes in order to minimize root blockage of the lines. This unplanted area would be used for plantation management purposes.

  For a 160 acre field in an area with low regional drainage, it was estimated that a 15 acre eucalyptus plantation (plus 2.2 acres in roads, harvest access, etc: totaling 17.2 acres) would be irrigated with drainwater. The plantation would then be drained into a 4.2 surface acre evaporation pond. This configuration would leave 130.5 acres in field crop production. Without a regulating reservoir, the plantation will be flooded during high rainfall periods.

  Figures D-2, D-3 and D-4 in the engineering appendix show typical designs for a 160-acre field with an evaporation pond and eucalyptus plantation.

- System Three - Evaporation Pond, Eucalyptus Plantation and Regulating Reservoir

This system is similar to System Two except that a regulating/tailwater reservoir has been added to store water until it is needed at optimum time for the eucalyptus plantation. Drainage flows enter at a low rate, are stored, then pumped out in a large volume. This optimizes eucalyptus utilization of the drain water and minimizes the amount of drainage from the plantation to the evaporation pond. This also allows the blending and recycling of high quality drain water.

For a 160-acre field in an area with high regional drainage flow, it is estimated that a 17.3-acre eucalyptus plantation (15 acres in trees, the rest in roads, harvest access, etc.), plus 12.2 acres of ponds and facilities would be needed. This configuration would leave 130.5 acres in crop production. In an area of low regional drainage, the same field would have 18.0 acres in eucalyptus, 10.2 acres of ponds and 131.8 acres of field crops.

Figures D-5, D-6 and D-7 show typical designs for a 160-acre field with an evaporation pond, eucalyptus plantation and regulating reservoir.

The analysis is displayed in Figure C-4 as a decision tree diagram similar to Figures C-1, C-2 and C-3. The following is a description of each of the variable elements in the comparison.

Pond Lining

The need for pond lining must be a site specific determination based on laboratory tests of the permeability of the soil after compaction, and the general nature of the groundwater beneath and near the pond location. Most ponds constructed to date have not needed pond lining.

Eucalyptus Plantation

Two choices are analyzed depending upon whether a eucalyptus plantation is included in the disposal system, or if only an evaporation pond is used.

Regulation Reservoir

The decision to include a regulating reservoir will depend upon the grower's desire to optimize water use. Including a reservoir allows the better quality drainwater to be blended in irrigation water and recycled. The reservoir also allows temporary storage of drainwater during winter rainfall when tree water use is low. It also allows for temporary water storage after tree harvest, until the plantation sprouts and re-establishes its water use. Without a reservoir there will be periods when the plantation and/or fields may be flooded, and will require more management attention to operate efficiently.

Regional Drainage Yield

Drainage systems will intercept water regardless of the original source. Some areas have subsurface flows moving into a field from up slope which will add to drainage yield. To reflect this, the analysis considers designs which must only dispose of applied irrigation/leaching water, and those which must accommodate subsurface flows. Figure D-10 in the Engineering Appendix shows those approximate areas where high regional drainage yields can be expected.

An example of a possible situation is shown in Figure C-4 as a dark line. In this example an unlined evaporation pond is needed and the grower has decided to use a eucalyptus plantation with a regulating reservoir. The 160 acre field is in an area of low regional drainage yield. The system will cost approximately $73,000 to install, and will require about $3,600 per year in operation and maintenance costs. The evaporation pond should have 3.5 surface acres with a 3 surface acre regulating pond as shown in Figure D-6. This combination will accommodate the drainage from 132 acres (gross) of field crops after it is used to irrigate 15 acres (net) of eucalyptus plantation.

SUMMARY

As is apparent with all the options, the net present value is much greater if pond lining is not required. When pond lining is required, no drain water disposal system provides a positive net present value.

When comparing the unlined pond options, the evaporation pond only option (i.e., without associated tree plantations) shows the greatest net present value with $140,000. This is followed by the pond/plantation options, all showing positive returns. Therefore, based on this analysis with its assumptions, the most economically justified alternative is the unlined evaporation pond without associated plantations.

The above situation changes if clay lining of evaporation ponds is needed to protect ground water or is required by some regulatory agency for environmental reasons. All the alternatives with associated plantations are much better than the evaporation pond alone. This is largely due to the high cost of pond construction being reduced by a need for a smaller pond with these options.

This analysis provides some idea of the relative economic impacts of the options studied. Please note that the set of circumstances for any individual grower will likely be different than the assumptions in this study; and therefore, they will need to weigh the recommendations accordingly. In addition, with any evaluation over a period of time, there is the potential for important factors to change, such as prices and technology, which could change the relative feasibility of the alternatives.

FIGURE C-1

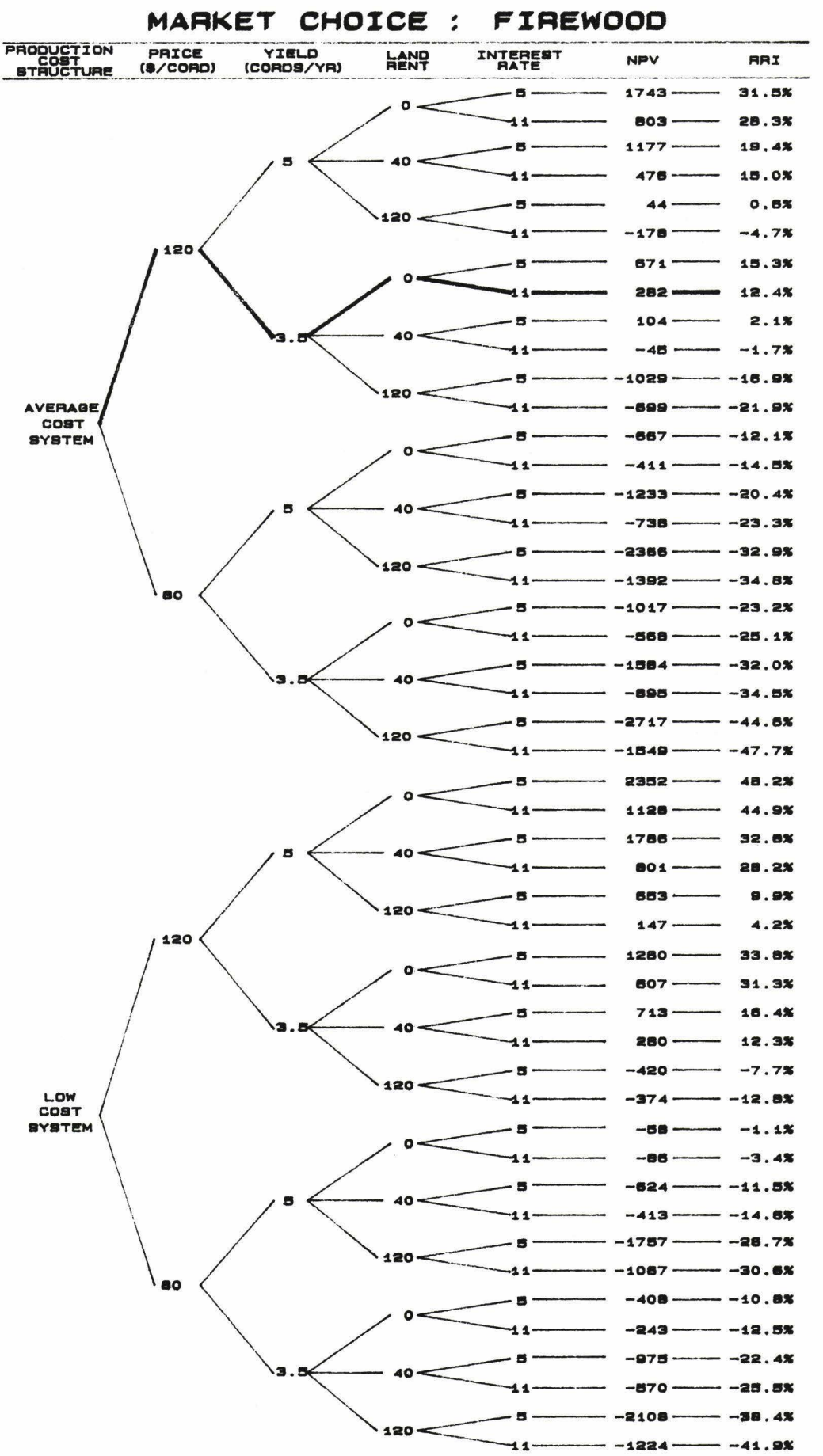
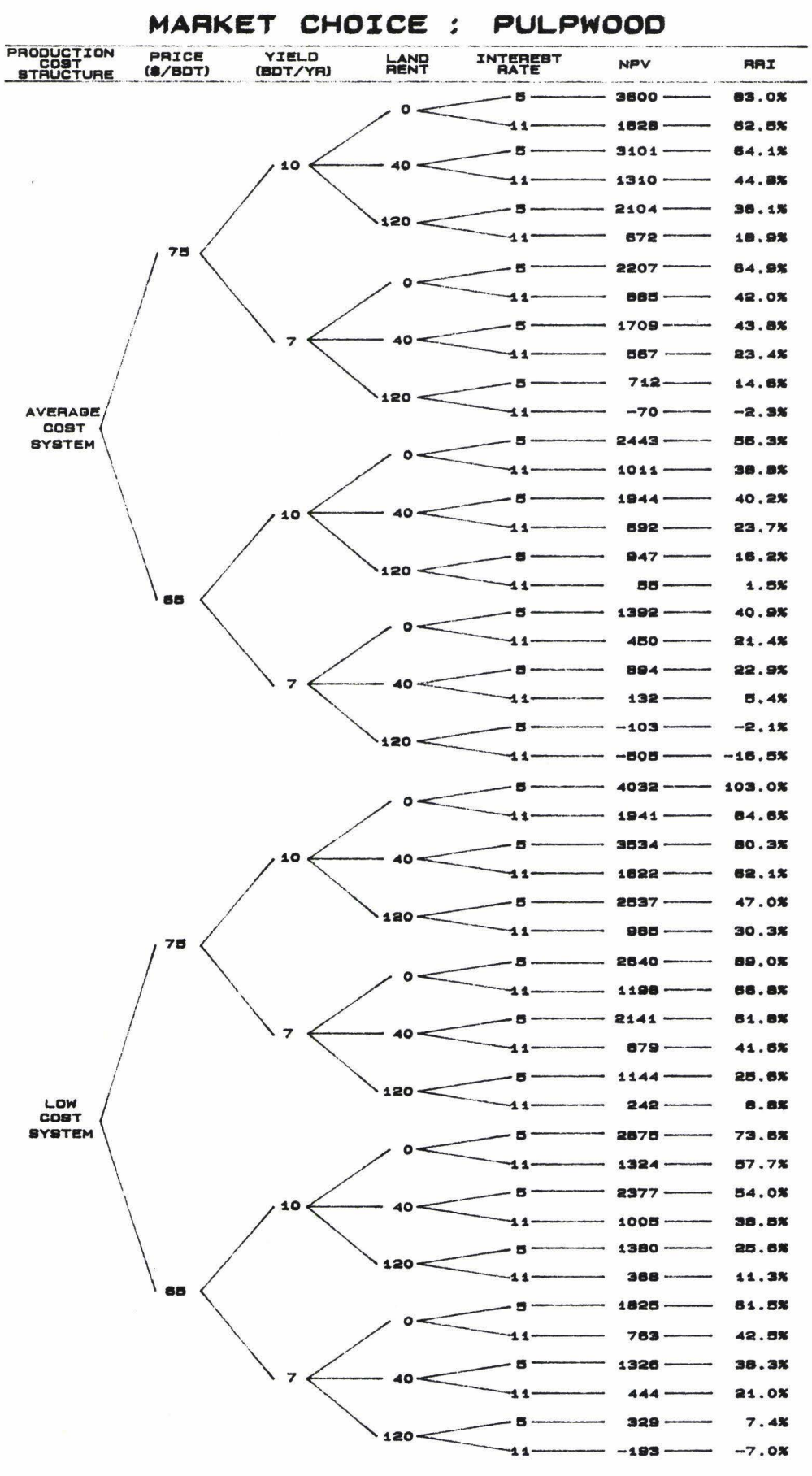
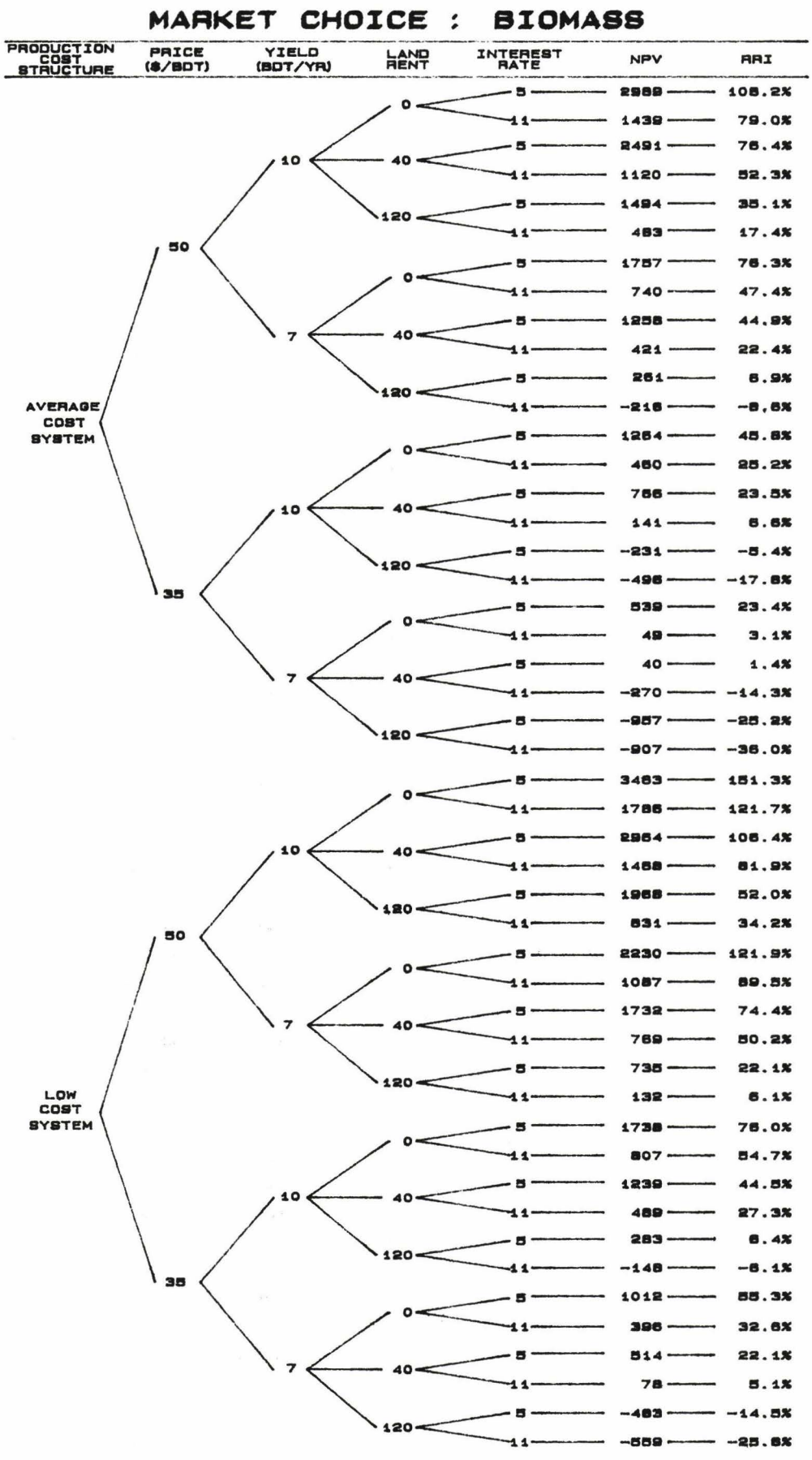

MARKET CHOICE : FIREWOOD
PRODUCTION COST STRUCTURE
PRICE ($/CORD)
YIELD (CORDS/YR)
LAND RENT
INTEREST RATE
NPV
RRI
AVERAGE COST SYSTEM
LOW COST SYSTEM
120
80
5
3.5
0
40
120
5
11
1743 31.5%
803 28.3%
1177 19.4%
476 15.0%
44 0.6%
-178 -4.7%
671 15.3%
282 12.4%
104 2.1%
-45 -1.7%
-1029 -16.9%
-699 -21.9%
-667 -12.1%
-411 -14.5%
-1233 -20.4%
-738 -23.3%
-2386 -32.9%
-1392 -34.8%
-1017 -23.2%
-568 -25.1%
-1584 -32.0%
-895 -34.5%
-2717 -44.6%
-1549 -47.7%
2352 48.2%
1128 44.9%
1786 32.8%
801 28.2%
553 9.9%
147 4.2%
1280 33.8%
807 31.3%
713 16.4%
280 12.3%
-420 -7.7%
-374 -12.8%
-58 -1.1%
-86 -3.4%
-624 -11.5%
-413 -14.8%
-1757 -28.7%
-1067 -30.8%
-408 -10.8%
-243 -12.5%
-975 -22.4%
-570 -25.5%
-2108 -38.4%
-1224 -41.9%

FIGURE C-2



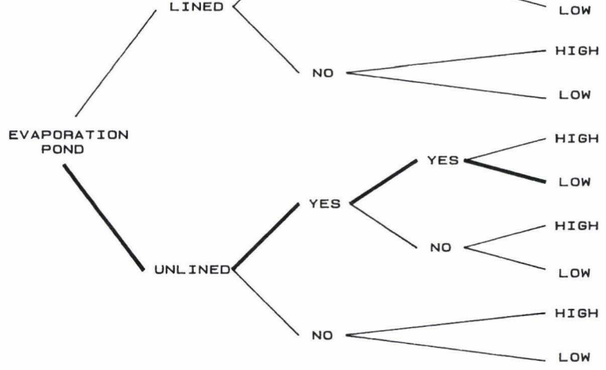
BDT = BONE DRY TON

FIGURE C-3



BDT = BONE DRY TON

EVALUATION OF DRAINWATER DISPOSAL SYSTEMS



POND LINING	EUCALYPTUS PLANTATION	REGULATING RESERVOIR	REGIONAL DRAINAGE YIELD	COSTS: INSTALLATION COSTS	COSTS: ANNUAL O & M COST	COSTS: PV OF O & M COST	COSTS: TOTAL PV COST	POND SIZE (ACRES): EVAP.	POND SIZE (ACRES): REG.	RETURNS: NO. OF ACRES OF FIELD CROPS	RETURNS: PV OF FIELD CROP INCOME (1190/Ac.)	RETURNS: NO. OF ACRES OF EUCALYPTUS	RETURNS: PV OF EUCALYPTUS INCOME (282/Ac.)	RETURNS: TOTAL PV INCOME	NET PV INCOME
LINED	YES	YES	HIGH	410, 000	4, 200	34, 700	447, 700	3.5	5.5	130.5	155, 295	15.0	4, 200	159, 500	-285, 200
			LOW	395, 000	3, 800	31, 100	426, 100	3.5	3.0	131.8	156, 800	15.0	4, 200	161, 000	-265, 100
		NO	HIGH	416, 000	2, 800	23, 100	439, 100	4.2	---	132.5	157, 700	20.0	5, 600	163, 300	-275, 800
			LOW	416, 000	2, 800	23, 100	439, 100	4.2	---	137.5	163, 600	15.0	4, 200	167, 800	-271, 300
	NO		HIGH	1, 494, 000	2, 800	22, 700	1, 516, 700	22.0	---	135.0	160, 700	0.0	-0-	160, 700	-1, 356, 000
			LOW	778, 000	1, 800	15, 100	793, 100	8.0	---	150.1	178, 600	0.0	-0-	178, 600	-614, 500
UNLINED	YES	YES	HIGH	97, 600	4, 000	33, 100	130, 700	3.5	5.5	130.5	155, 300	15.0	4, 200	154, 500	28, 800
			LOW	72, 300	3, 600	39, 400	111, 700	3.5	3.0	131.8	156, 800	15.0	4, 200	161, 000	49, 300
		NO	HIGH	35, 300	2, 600	21, 500	56, 800	4.2	---	132.5	157, 700	20.0	5, 600	163, 300	106, 500
			LOW	35, 300	2, 600	21, 500	56, 800	4.2	---	137.5	163, 600	15.0	4, 200	167, 800	111, 000
	NO		HIGH	44, 200	2, 400	19, 400	63, 600	22.0	---	135.0	160, 700	0.0	-0-	160, 700	97, 100
			LOW	25, 000	1, 600	13, 200	38, 200	8.0	---	150.1	178, 600	0.0	-0-	178, 600	140, 400

FIGURE C-4

TABLE C1

COST AND RETURN SPREADSHEET FOR THE PRODUCTION OF FIREWOOD

VARIABLES	
Labor cost (per hour)	5.65
Interest Rate	11 percent
Land Rent(per year)	0
Firewood Yield(cords/acre)	21
Firewood Value(per ton)	120

SUMMARY	
PV Costs	-2266
PV Returns	2548
Net PV	282
RRI (%)	12.4

%	Interest Rate
0	0
5	0
11	1
	1=yes,0=no

CASH FLOW:

Year	PV Costs	PV Returns	Year	PV Costs	PV Returns
1	-556.24	0.00	14	-7.68	0.00
2	-70.07	0.00	15	-6.92	0.00
3	-24.22	0.00	16	-6.24	0.00
4	-21.82	0.00	17	-130.30	0.00
5	-19.66	0.00	18	-89.89	385.11
6	-410.67	0.00	19	-11.89	0.00
7	-283.33	1213.78	20	-4.11	0.00
8	-37.46	0.00	21	-3.70	0.00
9	-12.95	0.00	22	-77.33	0.00
10	-11.66	0.00	23	-45.52	228.54
11	-243.71	0.00		-------	-------
12	-168.14	720.32	SUM	-2265.71	2547.75
13	-22.23	0.00			

OPERATION	LABOR (per hour)	FUEL/OIL (per hour)	EQUIPMENT REPAIRS (per hour)	EQUIPMENT DEPR. (per hour)	EQUIPMENT INTEREST (per hour)	HOURS PER ACRE	SUB TOTAL (per acre)	OTHER MATERIAL (type)	QUANTITY OF MATERIAL (per acre)	MATERIAL COST (per unit)	MATERIAL COST (per acre)	TOTAL COST (per acre)	TOTAL COST (per operation)	TOTAL COST (per year)	PV COSTS	PV RETURN
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(j)	(k)	(l)	(m)	(n)	(o)	(p)		
LAND PREPARATION (year 1)																
Disc.	-	-	2.52	4.4	0.44	0.7	5.152	none	0	0	0	-5.152	n/a	n/a		
w/90 hp tract.	5.65	9.64	2.71	2.58	0.26	0.7	14.588	none	0	0	0	-14.588	-19.74	n/a		
Harrow,Sprgtooth	-	-	1.84	1.35	0.14	0.25	0.8325	none	0	0	0	-0.8325	n/a	n/a		
w/90 hp tract.	5.65	9.64	2.71	2.58	0.26	0.25	5.21	none	0	0	0	-5.21	-6.0425	n/a		
Land Level	-	-	1	4.8	0.48	0.25	1.57	none	0	0	0	-1.57	n/a	n/a		
w/90 hp tract.	5.65	9.64	2.71	2.58	0.26	0.25	5.21	none	0	0	0	-5.21	-6.78	n/a		
List &	-	-	1.42	0.64	0.06	0.25	0.53	none	0	0	0	-0.53	n/a	n/a		
Preemergent Herb. (saddle tanks)	-	-	2.16	0.64	0.06	0.25	0.715	Treflan(gal)	1	39.5	39.5	-40.215	n/a	n/a		
w/90 hp tract.	5.65	9.64	2.71	2.58	0.26	0.25	5.21	none	0	0	0	-5.21	-45.955	n/a		
Sprinkler Irrig.	5.65	-	-	-	-	1	5.65	fresh wat.(acft	2	18.75	37.5	-43.15	n/a	n/a		
use of tract.	5.65	7.56	1.66	1.75	0.18	0.85	14.28	none	0	0	0	-14.28	n/a	n/a		
& setup(2 people)	11.3	-	-	-	-	0.85	9.605	none	0	0	0	-9.605	-67.035	n/a		
Tom. planter w/	-	-	1.53	2.5	0.25	1.1	4.708	trees	1210	0.2	242	-246.708	n/a	n/a		
60hp tract.4 peop	22.6	7.56	1.66	1.75	0.18	1.1	37.125	none	0	0	0	-37.125	n/a	n/a		
& supervision	12	-	-	-	-	1.1	13.2	none	0	0	0	-13.2	-297.033	n/a		
misc. operat. cost=labor trans.,superv.,records,office,pickup truck,int.oper. capital, roadways (=20 % of costs excluding land rent)													-88.5171	-531.1026		

OPERATION	LABOR (per hour)	FUEL/OIL (per hour)	EQUIPMENT REPAIRS (per hour)	EQUIPMENT DEPR. (per hour)	EQUIPMENT INTEREST (per hour)	HOURS PER ACRE	SUB TOTAL (per acre)	OTHER MATERIAL (type)	QUANTITY OF MATERIAL (per acre)	MATERIAL COST (per unit)	MATERIAL COST (per acre)	TOTAL COST (per acre)	TOTAL COST (per operation)	TOTAL COST (per year)	PV COSTS	PV RETURN
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(j)	(k)	(l)	(m)	(n)	(o)	(p)		
YEAR 1																
Weeding(herbic.)																
(1 person 3x)	16.95	-	-	-	-	1	16.95	roundup(qt)	1	20	20	-36.95	n/a	n/a		
w/3-wheel rig		0.9	0.6	1.8	0.18	0.5	1.74	none	0	0	0	-1.74	n/a	n/a		
& hand weeding	5.65	-	-	-	-	1	5.65	none	0	0	0	-5.65	-44.34	n/a		
Irrigat. 6 times	5.65	-	-	-	-	4	22.6	water	0	0	0	-22.6	n/a	n/a		
Power cost--charged to crop rotation			-	-	-	-	-									
repairs-$1 per ft	1	0	0	0	0	5	5	none	0	0	0	-5	-27.6	n/a		
Land rent	-	-	-	-	-	-	-	-	-	-	-	-	0	n/a		
misc. operat. cost=labor trans.,superv.,records,office,pickup truck,int.oper. capital, roadways (=20 % of yearly costs excluding land rent)													-14.388	-86.328	-556.243	
YEAR 2																
Weeding(herbic.)																
(1 person 3x)	16.95	-	-	-	-	1	16.95	roundup(qt)	1	20	20	-36.95	n/a	n/a		
w/3-wheel rig		0.9	0.6	1.8	0.18	0.5	1.74	none	0	0	0	-1.74	n/a	n/a		
& hand weeding	5.65	-	-	-	-	1	5.65	none	0	0	0	-5.65	-44.34	n/a		
Irrigat. 6 times	5.65	-	-	-	-	4	22.6	water	0	0	0	-22.6	n/a	n/a		
Power cost--charged to crop rotation			-	-	-	-	-									
repairs-$1 per ft	1	0	0	0	0	5	5	none	0	0	0	-5	-27.6	n/a		
Land rent	-	-	-	-	-	-	-	-	-	-	-	-	0	n/a		
misc. operat. cost=labor trans.,superv.,records,office,pickup truck,int.oper. capital, roadways (=20 % of yearly costs excluding land rent)													-14.388	-86.328	-70.0655	
YEAR 3																
Irrigat. 6 times	5.65	-	-	-	-	4	22.6	water	0	0	0	-22.6	n/a	n/a		
Power cost--charged to crop rotation			-	-	-	-	-									
repairs-$1 per ft	1	0	0	0	0	5	5	none	0	0	0	-5	-27.6	n/a		
Land rent	-	-	-	-	-	-	-	-	-	-	-	-	0	n/a		
misc. operat. cost=labor trans.,superv.,records,office,pickup truck,int.oper. capital, roadways (=20 % of yearly costs excluding land rent)													-5.52	-33.12	-24.2170	

OPERATION	LABOR (per hour)	FUEL/OIL (per hour)	EQUIPMENT REPAIRS (per hour)	EQUIPMENT DEPR. (per hour)	EQUIPMENT INTEREST (per hour)	HOURS PER ACRE	SUB TOTAL (per acre)	OTHER MATERIAL (type)	QUANTITY OF MATERIAL (per acre)	MATERIAL COST (per unit)	MATERIAL COST (per acre)	TOTAL COST (per acre)	TOTAL COST (per operation)	TOTAL COST (per year)	PV COSTS	PV RETURN
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(j)	(k)	(l)	(m)	(n)	(o)	(p)		
YEAR 4																
Irrigat. 6 times	5.65	-	-	-	-	4	22.6	water	0	0	0	-22.6	n/a	n/a		
Power cost--charged to crop rotation			-	-	-	-	-									
repairs-$1 per ft	1	0	0	0	0	5	5	none	0	0	0	-5	-27.6	n/a		
Land rent	-	-	-	-	-	-	-	-	-	-	-	-	0	n/a		
misc. operat. cost=labor trans.,superv.,records,office,pickup truck,int.oper. capital, roadways (=20 % of yearly costs excluding land rent)													-5.52		-33.12	-21.8171
YEAR 5																
Irrigat. 6 times	5.65	-	-	-	-	4	22.6	water	0	0	0	-22.6	n/a	n/a		
Power cost--charged to crop rotation			-	-	-	-	-									
repairs-$1 per ft	1	0	0	0	0	5	5	none	0	0	0	-5	-27.6	n/a		
Land rent	-	-	-	-	-	-	-	-	-	-	-	-	0	n/a		
misc. operat. cost=labor trans.,superv.,records,office,pickup truck,int.oper. capital, roadways (=20 % of yearly costs excluding land rent)													-5.52		-33.12	-19.6550
YEAR 6																
Irrigat. 6 times	5.65	-	-	-	-	4	22.6	water	0	0	0	-22.6	n/a	n/a		
Power cost--charged to crop rotation			-	-	-	-	-									
repairs-$1 per ft	1	0	0	0	0	5	5	none	0	0	0	-5	-27.6	n/a		
Land rent	-	-	-	-	-	-	-	-	-	-	-	-	0	n/a		
misc. operat. cost=labor trans.,superv.,records,office,pickup truck,int.oper. capital, roadways (=20 % of yearly costs excluding land rent)													-5.52		-33.12	-17.7072

YEAR 6 OPTION TO HARVEST FUELWOOD
Costs

Harvest Cost (per cd)	Fuelwood Yield (cords/ac/6yrs)	Cost ($/acre)
35	21	735

Fuelwood Harvest Cost	
-735	-392.960

OPERATION	LABOR (per hour)	FUEL/OIL (per hour)	EQUIPMENT REPAIRS (per hour)	EQUIPMENT DEPR. (per hour)	EQUIPMENT INTEREST (per hour)	HOURS PER ACRE	SUB TOTAL (per acre)	OTHER MATERIAL (type)	QUANTITY OF MATERIAL (per acre)	MATERIAL COST (per unit)	MATERIAL COST (per acre)	TOTAL COST (per acre)	TOTAL COST (per operation)	TOTAL COST (per year)	PV COSTS	PV RETURN
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(j)	(k)	(l)	(m)	(n)	(o)	(p)		
YEAR 7																
Weeding(herbic.)																
(1 person 3x)	16.95	-	-	-	-	1	16.95	roundup(qt)	1	20	20	-36.95	n/a	n/a		
w/3-wheel rig		0.9	0.6	1.8	0.18	0.5	1.74	none	0	0	0	-1.74	n/a	n/a		
& hand weeding	5.65	-	-	-	-	1	5.65	none	0	0	0	-5.65	-44.34	n/a		
Irrigat. 6 times	5.65	-	-	-	-	4	22.6	water	0	0	0	-22.6	n/a	n/a		
Power cost--charged to crop rotation			-	-	-	-	-									
repairs-$1 per ft	1	0	0	0	0	5	5	none	0	0	0	-5	-27.6	n/a		
Land rent	-	-	-	-	-	-	-	-	-	-	-	-	0	n/a		
misc. operat. cost=labor trans.,superv.,records,office,pickup truck,int.oper. capital, roadways (=20 % of yearly costs excluding land rent)													-14.388	-86.328	-41.5807	

YEAR 7 OPTION TO SELL FUELWOOD
Loading/Hauling Costs

Loading Cost (per cord)	Hauling Cost (per cord)	Yield(cords/ acre/6 yrs)	Cost ($/acre)	Haul/Load Cost		
5.65	18.25	21	501.9	-501.9	-241.745	

Returns from Fuelwood

Fuelwood Yield (cord/ac/6yr)	Fuelwood Value (per cord)	Fuelwood Value (per acre)	Biomass Value		
21	120	2520	2520	1213.783	

YEAR 8																
Weeding(herbic.)																
(1 person 3x)	16.95	-	-	-	-	1	16.95	roundup(qt)	1	20	20	-36.95	n/a	n/a		
w/3-wheel rig		0.9	0.6	1.8	0.18	0.5	1.74	none	0	0	0	-1.74	n/a	n/a		
& hand weeding	5.65	-	-	-	-	1	5.65	none	0	0	0	-5.65	-44.34	n/a		
Irrigat. 6 times	5.65	-	-	-	-	4	22.6	water	0	0	0	-22.6	n/a	n/a		
Power cost--charged to crop rotation			-	-	-	-	-									
repairs-$1 per ft	1	0	0	0	0	5	5	none	0	0	0	-5	-27.6	n/a		
Land rent	-	-	-	-	-	-	-	-	-	-	-	-	0	n/a		
misc. operat. cost=labor trans.,superv.,records,office,pickup truck,int.oper. capital, roadways (=20 % of yearly costs excluding land rent)													-14.388	-86.328	-37.4603	

OPERATION	LABOR (per hour)	FUEL/OIL (per hour)	EQUIPMENT REPAIRS (per hour)	EQUIPMENT DEPR. (per hour)	EQUIPMENT INTEREST (per hour)	HOURS PER ACRE	SUB TOTAL (per acre)	OTHER MATERIAL (type)	QUANTITY OF MATERIAL (per acre)	MATERIAL COST (per unit)	MATERIAL COST (per acre)	TOTAL COST (per acre)	TOTAL COST (per operation)	TOTAL COST (per year)	PV COSTS	PV RETURN
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(j)	(k)	(l)	(m)	(n)	(o)	(p)		
YEAR 9																
Irrigat. 6 times	5.65	-	-	-	-	4	22.6	water	0	0	0	-22.6	n/a	n/a		
Power cost--charged to crop rotation			-	-	-	-	-									
repairs-$1 per ft	1	0	0	0	0	5	5	none	0	0	0	-5	-27.6	n/a		
Land rent	-	-	-	-	-	-	-	-	-	-	-	-	0	n/a		
misc. operat. cost=labor trans.,superv.,records,office,pickup truck,int.oper. capital, roadways (=20 % of yearly costs excluding land rent)													-5.52		-33.12	-12.9472
YEAR 10																
Irrigat. 6 times	5.65	-	-	-	-	4	22.6	water	0	0	0	-22.6	n/a	n/a		
Power cost--charged to crop rotation			-	-	-	-	-									
repairs-$1 per ft	1	0	0	0	0	5	5	none	0	0	0	-5	-27.6	n/a		
Land rent	-	-	-	-	-	-	-	-	-	-	-	-	0	n/a		
misc. operat. cost=labor trans.,superv.,records,office,pickup truck,int.oper. capital, roadways (=20 % of yearly costs excluding land rent)													-5.52		-33.12	-11.6642
YEAR 11																
Irrigat. 6 times	5.65	-	-	-	-	4	22.6	water	0	0	0	-22.6	n/a	n/a		
Power cost--charged to crop rotation			-	-	-	-	-									
repairs-$1 per ft	1	0	0	0	0	5	5	none	0	0	0	-5	-27.6	n/a		
Land rent	-	-	-	-	-	-	-	-	-	-	-	-	0	n/a		
misc. operat. cost=labor trans.,superv.,records,office,pickup truck,int.oper. capital, roadways (=20 % of yearly costs excluding land rent)													-5.52		-33.12	-10.5083

YEAR 11 OPTION TO HARVEST FUELWOOD

Costs

Harvest Cost (per cd)	Fuelwood Yield (cords/ac/6yrs)	Cost ($/acre)
35	21	735

Fuelwood Harvest Cost	
-735	-233.200

OPERATION	LABOR (per hour)	FUEL/OIL (per hour)	EQUIPMENT REPAIRS (per hour)	EQUIPMENT DEPR. (per hour)	EQUIPMENT INTEREST (per hour)	HOURS PER ACRE	SUB TOTAL (per acre)	OTHER MATERIAL (type)	QUANTITY OF MATERIAL (per acre)	MATERIAL COST (per unit)	MATERIAL COST (per acre)	TOTAL COST (per acre)	TOTAL COST (per operation)	TOTAL COST (per year)	PV COSTS	PV RETURN
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(j)	(k)	(l)	(m)	(n)	(o)	(p)		
YEAR 12																
Weeding(herbic.)																
(1 person 3x)	16.95	-	-	-	-	1	16.95	roundup(qt)	1	20	20	-36.95	n/a	n/a		
w/3-wheel rig		0.9	0.6	1.8	0.18	0.5	1.74	none	0	0	0	-1.74	n/a	n/a		
& hand weeding	5.65	-	-	-	-	1	5.65	none	0	0	0	-5.65	-44.34	n/a		
Irrigat. 6 times	5.65	-	-	-	-	4	22.6	water	0	0	0	-22.6	n/a	n/a		
Power cost--charged to crop rotation			-	-	-	-	-									
repairs-$1 per ft	1	0	0	0	0	5	5	none	0	0	0	-5	-27.6	n/a		
Land rent	-	-	-	-	-	-	-	-	-	-	-	-	0	n/a		
misc. operat. cost=labor trans.,superv.,records,office,pickup truck,int.oper. capital, roadways (=20 % of yearly costs excluding land rent)													-14.388	-86.328	-24.6759	

YEAR 12 OPTION TO SELL FUELWOOD

Loading/Hauling Costs

Loading Cost (per cord)	Hauling Cost (per cord)	Yield(cords/ acre/6 yrs)	Cost ($/acre)	Haul/Load Cost	
5.65	18.25	21	501.9	-501.9	-143.463

Returns from Fuelwood

Fuelwood Yield (cord/ac/6yr)	Fuelwood Value (per cord)	Fuelwood Value (per acre)	Biomass Value	
21	120	2520	2520	720.3168

YEAR 13																
Weeding(herbic.)																
(1 person 3x)	16.95	-	-	-	-	1	16.95	roundup(qt)	1	20	20	-36.95	n/a	n/a		
w/3-wheel rig		0.9	0.6	1.8	0.18	0.5	1.74	none	0	0	0	-1.74	n/a	n/a		
& hand weeding	5.65	-	-	-	-	1	5.65	none	0	0	0	-5.65	-44.34	n/a		
Irrigat. 6 times	5.65	-	-	-	-	4	22.6	water	0	0	0	-22.6	n/a	n/a		
Power cost--charged to crop rotation			-	-	-	-	-									
repairs-$1 per ft	1	0	0	0	0	5	5	none	0	0	0	-5	-27.6	n/a		
Land rent	-	-	-	-	-	-	-	-	-	-	-	-	0	n/a		
misc. operat. cost=labor trans.,superv.,records,office,pickup truck,int.oper. capital, roadways (=20 % of yearly costs excluding land rent)													-14.388	-86.328	-22.2303	

OPERATION	LABOR (per hour)	FUEL/OIL (per hour)	EQUIPMENT REPAIRS (per hour)	EQUIPMENT DEPR. (per hour)	EQUIPMENT INTEREST (per hour)	HOURS PER ACRE	SUB TOTAL (per acre)	OTHER MATERIAL (type)	QUANTITY OF MATERIAL (per acre)	MATERIAL COST (per unit)	MATERIAL COST (per acre)	TOTAL COST (per acre)	TOTAL COST (per operation)	TOTAL COST (per year)	PV COSTS	PV RETURN
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(j)	(k)	(l)	(m)	(n)	(o)	(p)		
YEAR 14																
Irrigat. 6 times	5.65	-	-	-	-	4	22.6	water	0		0	0	-22.6	n/a	n/a	
Power cost--charged to crop rotation			-	-	-	-	-									
repairs-$1 per ft	1	0	0	0	0	5	5	none	0		0	0	-5	-27.6	n/a	
Land rent	-	-	-	-	-	-	-	-	-	-	-	-	-	0	n/a	
misc. operat. cost=labor trans.,superv.,records,office,pickup truck,int.oper. capital, roadways (=20 % of yearly costs excluding land rent)													-5.52	-33.12	-7.68350	
YEAR 15																
Irrigat. 6 times	5.65	-	-	-	-	4	22.6	water	0		0	0	-22.6	n/a	n/a	
Power cost--charged to crop rotation			-	-	-	-	-									
repairs-$1 per ft	1	0	0	0	0	5	5	none	0		0	0	-5	-27.6	n/a	
Land rent	-	-	-	-	-	-	-	-	-	-	-	-	-	0	n/a	
misc. operat. cost=labor trans.,superv.,records,office,pickup truck,int.oper. capital, roadways (=20 % of yearly costs excluding land rent)													-5.52	-33.12	-6.92208	
YEAR 16																
Irrigat. 6 times	5.65	-	-	-	-	4	22.6	water	0		0	0	-22.6	n/a	n/a	
Power cost--charged to crop rotation			-	-	-	-	-									
repairs-$1 per ft	1	0	0	0	0	5	5	none	0		0	0	-5	-27.6	n/a	
Land rent	-	-	-	-	-	-	-	-	-	-	-	-	-	0	n/a	
misc. operat. cost=labor trans.,superv.,records,office,pickup truck,int.oper. capital, roadways (=20 % of yearly costs excluding land rent)													-5.52	-33.12	-6.23616	
YEAR 17																
Irrigat. 6 times	5.65	-	-	-	-	4	22.6	water	0		0	0	-22.6	n/a	n/a	
Power cost--charged to crop rotation			-	-	-	-	-									
repairs-$1 per ft	1	0	0	0	0	5	5	none	0		0	0	-5	-27.6	n/a	
Land rent	-	-	-	-	-	-	-	-	-	-	-	-	-	0	n/a	
misc. operat. cost=labor trans.,superv.,records,office,pickup truck,int.oper. capital, roadways (=20 % of yearly costs excluding land rent)													-5.52	-33.12	-5.61814	
YEAR 17 OPTION TO HARVEST FUELWOOD																
Harvest Cost (per cd)	Fuelwood Yield (cords/ac/6yrs)		Cost ($/acre)											Fuelwood Harvest Cost		
35	21		735											-735	-124.678	

OPERATION	LABOR (per hour)	FUEL/OIL (per hour)	EQUIPMENT REPAIRS (per hour)	EQUIPMENT DEPR. (per hour)	EQUIPMENT INTEREST (per hour)	HOURS PER ACRE	SUB TOTAL (per acre)	OTHER MATERIAL (type)	QUANTITY OF MATERIAL (per acre)	MATERIAL COST (per unit)	MATERIAL COST (per acre)	TOTAL COST (per acre)	TOTAL COST (per operation)	TOTAL COST (per year)	PV COSTS	PV RETURN
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(j)	(k)	(l)	(m)	(n)	(o)	(p)		
YEAR 18																
Weeding(herbic.)																
(1 person 3x)	16.95	-	-	-	-	1	16.95	roundup(qt)	1	20	20	-36.95	n/a	n/a		
w/3-wheel rig		0.9	0.6	1.8	0.18	0.5	1.74	none	0	0	0	-1.74	n/a	n/a		
& hand weeding	5.65	-	-	-	-	1	5.65	none	0	0	0	-5.65	-44.34	n/a		
Irrigat. 6 times	5.65	-	-	-	-	4	22.6	water	0	0	0	-22.6	n/a	n/a		
Power cost--charged to crop rotation			-	-	-	-	-									
repairs-$1 per ft	1	0	0	0	0	5	5	none	0	0	0	-5	-27.6	n/a		
Land rent	-	-	-	-	-	-	-	-	-	-	-	-	0	n/a		
misc. operat. cost=labor trans.,superv.,records,office,pickup truck,int.oper. capital, roadways (=20 % of yearly costs excluding land rent)													-14.388	-86.328	-13.1926	

YEAR 18 OPTION TO SELL FUELWOOD

Loading/Hauling Costs

Loading Cost (per cord)	Hauling Cost (per cord)	Yield(cords/ acre/6 yrs)	Cost ($/acre)	Haul/Load Cost		
5.65	18.25	21	501.9	-501.9	-76.7003	

Returns from Fuelwood

Fuelwood Yield (cord/ac/6yr)	Fuelwood Value (per cord)	Fuelwood Value (per acre)	Biomass Value		
21	120	2520	2520	385.1064	

YEAR 19																
Weeding(herbic.)																
(1 person 3x)	16.95	-	-	-	-	1	16.95	roundup(qt)	1	20	20	-36.95	n/a	n/a		
w/3-wheel rig		0.9	0.6	1.8	0.18	0.5	1.74	none	0	0	0	-1.74	n/a	n/a		
& hand weeding	5.65	-	-	-	-	1	5.65	none	0	0	0	-5.65	-44.34	n/a		
Irrigat. 6 times	5.65	-	-	-	-	4	22.6	water	0	0	0	-22.6	n/a	n/a		
Power cost--charged to crop rotation			-	-	-	-	-									
repairs-$1 per ft	1	0	0	0	0	5	5	none	0	0	0	-5	-27.6	n/a		
Land rent	-	-	-	-	-	-	-	-	-	-	-	-	0	n/a		
misc. operat. cost=labor trans.,superv.,records,office,pickup truck,int.oper. capital, roadways (=20 % of yearly costs excluding land rent)													-14.388	-86.328	-11.8856	

OPERATION	LABOR (per hour)	FUEL/OIL (per hour)	EQUIPMENT REPAIRS (per hour)	EQUIPMENT DEPR. (per hour)	EQUIPMENT INTEREST (per hour)	HOURS PER ACRE	SUB TOTAL (per acre)	OTHER MATERIAL (type)	QUANTITY OF MATERIAL (per acre)	MATERIAL COST (per unit)	MATERIAL COST (per acre)	TOTAL COST (per acre)	TOTAL COST (per operation)	TOTAL COST (per year)	PV COSTS	PV RETURN
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(j)	(k)	(l)	(m)	(n)	(o)	(p)		
YEAR 20																
Irrigat. 6 times	5.65	-	-	-	-	4	22.6	water	0	0	0	-22.6	n/a	n/a		
Power cost--charged to crop rotation			-	-	-	-	-									
repairs-$1 per ft	1	0	0	0	0	5	5	none	0	0	0	-5	-27.6	n/a		
Land rent	-	-	-	-	-	-	-	-	-	-	-	-	0	n/a		
misc. operat. cost=labor trans.,superv.,records,office,pickup truck,int.oper. capital, roadways (=20 % of yearly costs excluding land rent)													-5.52		-33.12	-4.10787
YEAR 21																
Irrigat. 6 times	5.65	-	-	-	-	4	22.6	water	0	0	0	-22.6	n/a	n/a		
Power cost--charged to crop rotation			-	-	-	-	-									
repairs-$1 per ft	1	0	0	0	0	5	5	none	0	0	0	-5	-27.6	n/a		
Land rent	-	-	-	-	-	-	-	-	-	-	-	-	0	n/a		
misc. operat. cost=labor trans.,superv.,records,office,pickup truck,int.oper. capital, roadways (=20 % of yearly costs excluding land rent)													-5.52		-33.12	-3.70082
YEAR 22																
Irrigat. 6 times	5.65	-	-	-	-	4	22.6	water	0	0	0	-22.6	n/a	n/a		
Power cost--charged to crop rotation			-	-	-	-	-									
repairs-$1 per ft	1	0	0	0	0	5	5	none	0	0	0	-5	-27.6	n/a		
Land rent	-	-	-	-	-	-	-	-	-	-	-	-	0	n/a		
misc. operat. cost=labor trans.,superv.,records,office,pickup truck,int.oper. capital, roadways (=20 % of yearly costs excluding land rent)													-5.52		-33.12	-3.33419

YEAR 22 OPTION TO HARVEST FUELWOOD
Costs

Harvest Cost (per cd)	Fuelwood Yield (cords/ac/6yrs)	Cost ($/acre)	Fuelwood Harvest Cost	
35	21	735	-735	-73.9924

OPERATION	LABOR (per hour)	FUEL/OIL (per hour)	EQUIPMENT REPAIRS (per hour)	EQUIPMENT DEPR. (per hour)	EQUIPMENT INTEREST (per hour)	HOURS PER ACRE	SUB TOTAL (per acre)	OTHER MATERIAL (type)	QUANTITY OF MATERIAL (per acre)	MATERIAL COST (per unit)	MATERIAL COST (per acre)	TOTAL COST (per acre)	TOTAL COST (per operation)	TOTAL COST (per year)	PV COSTS	PV RETURN
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(j)	(k)	(l)	(m)	(n)	(o)	(p)		

YEAR 23 OPTION TO SELL FUELWOOD
Loading/Hauling Costs

Loading Cost (per cord)	Hauling Cost (per cord)	Yield(cords/ acre/6 yrs)	Cost ($/acre)	Haul/Load Cost		
5.65	18.25	21	501.9	-501.9	-45.5173	

Returns from Fuelwood

Fuelwood Yield (cord/ac/6yr)	Fuelwood Value (per cord)	Fuelwood Value (per acre)	Biomass Value		
21	120	2520	2520	228.5388	

APPENDIX D. Engineering

ENGINEERING DESIGN EVALUATIONS

The designs developed for this study used a range of high, low and average regional drainage yield conditions that would exist for an average block of 160 acres of cropland in the study area.

The 160 acres of cropland were assumed to have existing drainage facilities, irrigation systems and tailwater return systems. It was also assumed that there was no evaporation pond on the block and that drainlines were either not permanently blocked or had recently been blocked.

Average rainfall and evaporation data from the CIMIS station near Hanford, California, were used to determine drainage volumes, consumptive use and pond evaporation.

Soil data was obtained from unpublished SCS Soil Form 5s, developed during soil surveys of the area.

It was determined that a crop rotation of cotton-cotton-grain was the most prevalent and would be used to determine consumptive use and drainage yields. Eucalyptus was used as the agroforestry crop to determine equivalent consumptive use and drainage yields.

Consumptive use (CU) for crops was determined using the Modified Blaney-Criddle Consumptive Use program and stored CIMIS data. CU was determined for alfalfa (50.89 in/yr), cotton (29.06 in/yr), grain (14.53 in/yr), tomatoes (26.41 in/yr), safflower (30.85 in/yr) and orchards (50.99 in/yr) to provide a range of design values. CU for eucalyptus (tree crop) was determined using the data from references that gave the use in percentage of pan evaporation and the Hanford pan evaporation rate. In this area, eucalyptus can be expected to use about 74-inches per year.

Irrigation was assumed to meet the full needs of the crops, plus leaching,at all times of the year. Irrigation efficiency was assumed to be 70 percent, although present practices are likely to have lower efficiencies. Leaching volumes are 15 percent for crops (based on Westlands Water District data and grower interviews) and 10 percent for eucalyptus to maintain soil salinity at reduced levels for crop growth and germination. A 5 percent leaching volume can be used for cotton if the irrigation is uniform, but a leaching cycle may be needed each five years to remove accumulated soil salts. Reduced irrigation of tree crops was not considered, though it is a viable alternative to reduce drainage volumes needing evaporation. The reduction of drainage volume from reducing irrigation occurs because the trees use ground water for CU rather than irrigation water; and therefore, no excess infiltrating water is generated. Under this scenario, leaching of salts will be done by rainfall or added irrigation water in the Spring. Recycling of drainage to crop irrigation was not considered, as the water quality could not easily be

determined and extensive salinity management would be needed. The drain water quality data available indicated more than half of the water exceeded 6,000 mg/l TDS, which is generally considered to be unacceptable.

Irrigation of the tree plantations was assumed to be by using cropland drainage water to the greatest extent possible. Well or imported water would be used to irrigate trees only when adequate drainage water was not available. Daily drainage volumes for each crop was determined by the SCS developed and revised Drain Design program. This program uses soil data, a range of irrigation efficiencies, CU, leaching requirement and effective rainfall to determine the amount or volume of drainage that could be expected for each crop.

The estimated regional drainage yield and the estimated deep percolation rates were obtained from published engineering study reports for the area. Both high and low regional drainage yields were used to provide a range of designs (sizes and costs) to be used as examples. The high regional yields are 0.023 in/day/ac, and the low regional yields are 0.001 in/day/ac. The deep percolation value, 0.000000007 cm/sec, reported for the Westlands area was used for all designs. For all practical purposes, zero was used for deep percolation.

The daily crop drainage yields, regional drainage yields and deep percolation were then combined into net drainage yields for each crop and converted to monthly values. The combined drainage yields were determined for both high and low regional yields.

The monthly drainage yields were then used in an electronic spreadsheet program to determine pond sizes for varying acreages of cropland. The program considered the sizes of drained areas, rainfall and evaporation, and average pond surface areas to size the ponds for accumulated storage. Both evaporation and regulation/tailwater ponds were designed to be dry for one month at the end of the dry season, though present WQCB rules require that evaporation ponds don't go dry unless the salts are removed to hazardous waste sites.

After the pond volumes and average areas were determined, an approximate layout was made on a field. The estimated areas were used to determine a layout that was apparently efficient for the space occupied. Only one layout was made for each alternate, no repetition was used to test efficiency.

The layouts of facilities used appeared to be efficient for the space occupied and provided a basis to compute quantities; and from the quantities, costs. The layouts were not intended to describe a standard. Costs used were average costs obtained from the Hanford Field Office.

Costs for evaporation ponds are for both lined and unlined ponds. Dependent on site conditions and tests, RWQCB requirements presently may cause many of the ponds to be lined. A four-foot

thick clay lining was assumed to meet the requirements, based on past installations and tests. For the study estimates, the clay was imported. Local clay sources could be used or it may be possible to rework on-site clay to meet the requirements. See Table A for possible cost variations. In all cases, laboratory tests will be needed to prove the lining permeability meets requirements (k=0.00000001 cm/sec or 0.000014 in/hr). Other types of linings may be used, such as double layer plastic linings. Monitoring systems and perimeter drains are required for evaporation ponds and were included in costs.

Based on water quality, it was assumed that regulation reservoirs/tailwater ponds do not need to be lined.

Alternatives that require considerable excavation and fill may be less costly if done when adjacent fields are reorganized.

Trees would not be planted closer than 10 feet to drainlines to reduce the potential for root clogging (20-foot wide access zone and road).

ALTERNATIVES

The alternatives chosen to analyze were suggested by the SCS Field Office and by the California Department of Food and Agriculture.

The alternatives are:

System One

1. Cropland and unlined evaporation pond (see Figure D-1 for low regional drainage yield sizing.)

2. Cropland and lined evaporation pond (no figure, lining added to pond)

System Two

1. Cropland, tree plantation, and unlined evaporation pond (see Figure D-2 for tree plantation storing winter runoff, high or low regional yield. See Figures D-3 and D-4 for evaporation pond storage of winter plantation drainage and runoff, and low and high regional drainage yield sizing.)

2. Cropland, tree plantation, and lined evaporation pond (No figure, lining added to pond)

System Three

1. Cropland, tree plantation, unlined evaporation pond, and regulation reservoir/tailwater pond (See Figure D-5 for high regional drainage yield sizing. See Figure D-6 for low regional drainage yield sizing. See Figure D-7 for low regional drainage yield sizing and gravity outflow regulation reservoir.)

A variation of Figures D-5 and D-6 was suggested. This alternate would have a raised regulation reservoir (no tailwater pond), such that irrigation of the tree plantation would be by gravity, saving one pump and sump and the attendant O&M costs. This alternate is shown on Figure D-7.

TABLE A. EXAMPLE 4-FOOT THICK CLAY LINING COSTS
Actual Needs Must be Determined by Site Tests

	IMPORTED CLAY (Bentonite @ 12.5 lbs/cy) and Compact	ON-SITE CLAY (Bentonite @ 12.5 lbs/cy) and Rework and Compact	ON-SITE CLAY Rework and compact Only
Clay Material	$10.25/cy	---	---
Bentonite ($200/ton)	1.25/cy	$ 1.25/cy	---
Mixing	0.50/cy	0.50/cy	---
Compaction	0.65/cy	0.65/cy	$ 0.65/cy
Trimming	0.30/cy	0.30/cy	0.30/cy
Excavation	1.05/cy	1.05/cy	1.05/cy
COST PER CY	$14.00	$ 3.75	$ 2.00
COST PER SF	$ 2.07	$ 0.55	$ 0.30

NOTES: No cost estimates for other lining types were made. It is assumed that other lining costs will be reasonably comparable to clay lining costs, with double plastic lining about $1.50/SF, where a concrete under layer is not needed.

QUANTITIES AND COSTS

Table B displays the quantities and costs of systems 1,2 and 3 for high and low regional drainage yields. Also shown are: quantities for cropland acres and drainage; pond sizes; and tree plantation size, drainage and irrigation. Average annual costs are shown as costs per acre-foot of cropland drainage for each system.

Comparisons between systems should only be made for the same regional drainage yield. On-farm systems require site specific designs and costs that reflect actual conditions.

Costs of drainwater treatment at a regional plant have been estimated to range from $100-$200 per AF, based on existing pilot plant costs and economics of scale. A gravity collector pipe system is estimated to cost an additional $12-$15 per AF.

OPERATION AND MAINTENANCE

Cropland drainlines are to be kept pumped for continuous, free flow. Drainlines for tree plantations may be intermittently pumped, with excess drainwater and runoff storage in the soil profile and on the plantation surface. Free flow in drainlines

allows positive management of reduce leaching and soil salinity. Lack of free flow in drainlines will cause excessive soil salinity and require additional leaching each 3 to 5 years. Jetting to clean drainlines of sediment is assumed to be needed twice during the 23-year design life. Replacement of sediment filled drainlines will increase O & M costs, but is an option.

Rice check size dikes, placed around tree plantations to control and retain surface flows from irrigation of rainfall, will need to be replaced each 3 years and maintained to reduce vegetation fire hazard and varmint damages.

Litter and leaves removed from the tree plantation to reduce fire hazard and allow proper cultivation should be burned and the ashes added to the evaporation pond salts for disposal at a Class II hazardous waste landfill.

Irrigation of cropland and tree plantations is assumed to be adequate to meet crop needs in quantity and timing and provide for full growth potential and adequate leaching. Irrigation scheduling will be made on the basis of site and crop requirements. Efforts should be made to obtain an irrigation efficiency of 80% or greater.

Pond levees should be grass covered on the top and other slopes, and maintained to reduce fire hazard from vegetation and to reduce animal damage. Damage to slopes from erosion or animal should be repaired each spring and a grass cover re-established. Sags and ruts in the top of the levee are to be refilled with earth from an off-levee source. Excavation or cuts in levee toes should not be allowed, but if made, should promptly be refilled with compacted earth.

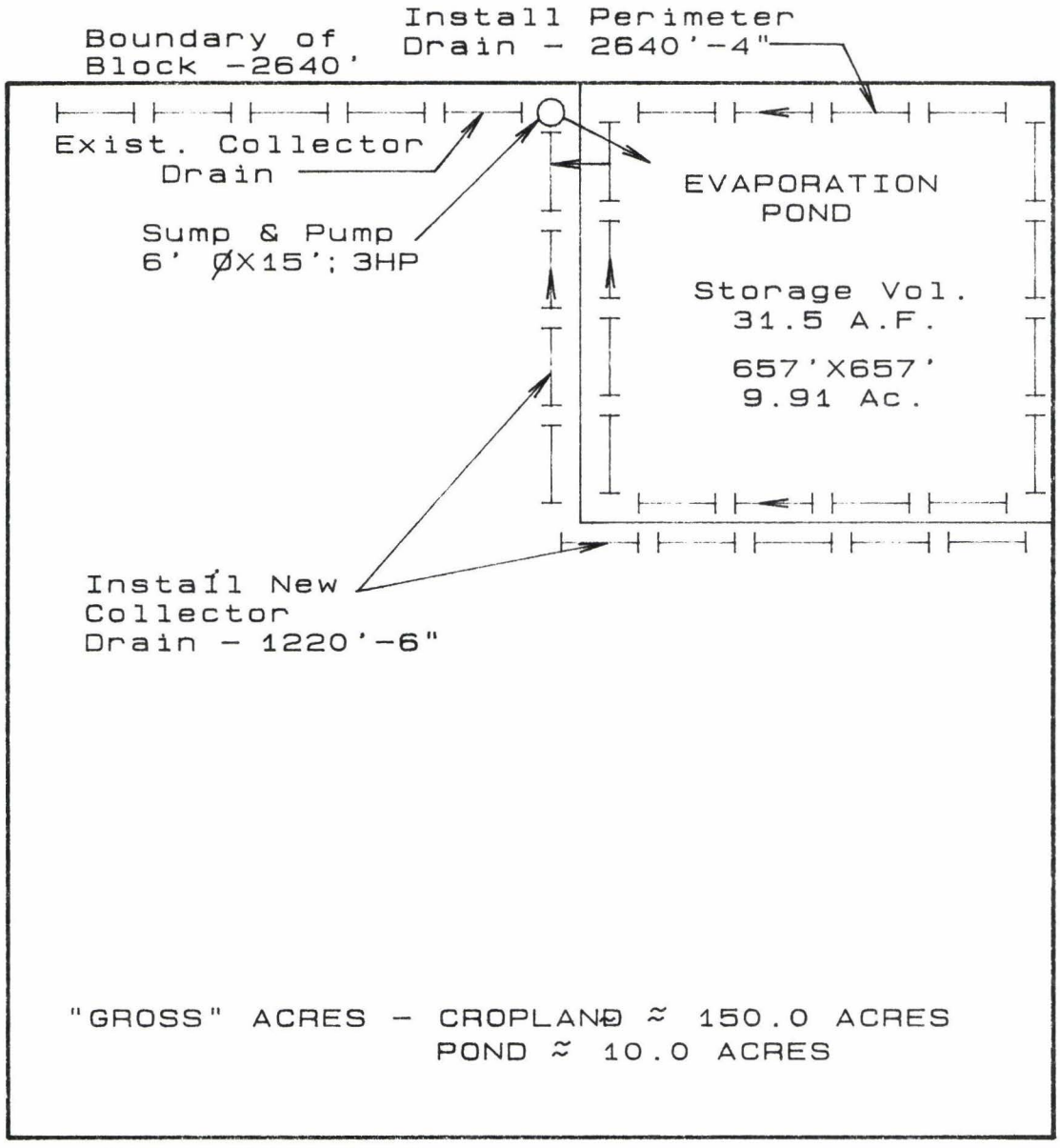
Evaporation ponds should be dried out each 2-3 years and the accumulated salts scraped up and removed. The salts can be stored in a water tight container until a sufficient quantity is obtained to haul to a Class II hazardous waste landfill. Unless salts are to be removed, the ponds should not be allowed to dry out. Monitoring wells around the ponds should be read in the spring, summer and fall to establish the water levels and determine if seepage is occurring. If seepage occurs, water quality samples will be needed each fall. If the seepage water quality exceeds the ambient groundwater quality by more than 10%, pond lining may be required. Lined ponds should have needed repairs made after salt removal. Vegetation should be discouraged inside evaporation pond levees and water levels maintained to reduce wildlife habitat and use.

Pumps, sumps and valves should be maintained on a regular basis and inspected at least once each year. Repairs should be made before the next use.

TABLE B - PANOCHE CREEK SALINITY STUDY
QUANTITIES AND COSTS

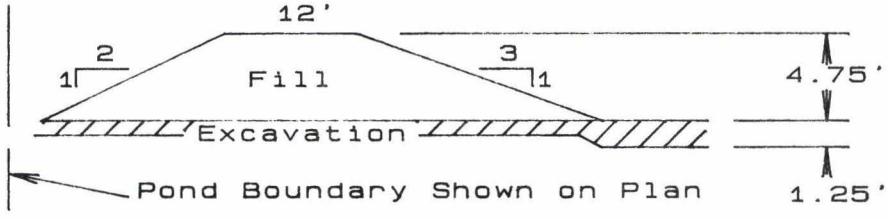
DESCRIPTION	SYSTEM ONE - CROPLAND AND EVAPORATION POND High Regional Drainage Yield UNITS	INSTALL COSTS, $	O & M 1 COSTS,$	SYSTEM TWO - CROPLAND, EVAPORATION AND EUCALYPTUS (20 Acres) High Regional Drainage Yield UNITS	INSTALL COSTS,$	O & M 1/ COSTS,$	SYSTEM THREE - CROPLAND, EVAPORATION POND, REGULATION/TAILWATER POND AND EUCALYPTUS (15 Acres) High Regional Drainage Yield UNITS	INSTALL COSTS,$	O & M 1/ COSTS,$
Cropland, Acres	135			133			129		
Cropland Drainage, AF/yr	102			99			97		
Evap. Pond - Surf. Area, Ac.	21			4			4		
- Gross Area, Ac.	25			5			5		
Reg/Sto. Pond - Surf. Area, Ac							6		
- Gross Area, Ac							7		
Eucalyptus - Gross Area, Ac				22			20		
- Planted Area, Ac				20			15		
- Drainage, AF/Yr				33			29		
-Irrigation, AF/yr 2/				43			10		
COLLECTOR DRAIN (New Location)									
Drainline	4" - 600' 6" - 1,400'	3,160	50	4"- 800' 6"- 900' 8"- 700'	4,620	56	4"- 800' 6"- 900' 8"- 700'	4,620	56
Sump and Pump, 6'x15', 3HP		7,615	460		7,615	460		7,615	460
IRRIGATION LINE TO TREES				"6"- 450'	1,110	560 incl. rice dikes	6"- 2,340'	5,780	170
DRAINLINE FOR TREES									
Drainline				4"- 3,600' 6"- 580'	4,900	100	4"- 3,680 6"- 400'	4,660	95
Sump and Pump, 6'x15',3HP					7,615	375		7,615	375
REGULATION/TAILWATER POND									
Pond Install., cut and fill							27,380 cy	55,700	1,670
Sump and Pump, 6'x15', 5HP								7,940	800
EVAPORTATION POND (Unlined)									
Pond Install., cut and fill	25,600 cy	27,900	1,000	5,830 cy	6,140	490	3/		
Perimeter Drain, 4" tile	4,020 Lf	4,300	95	2,030 LF	2,170	50	2,300 LF	2,460	55
Monitoring, 5 stations		1,175	740		1,175	740		1,175	740
INSTALLATION TOTALS (Unlined Pond)		44,150	2,345		35,345	2,831		97,565	4,421
EVAPORATION POND LINING(As Needed)	1,000,000 SF	1,450,000	400	183,900 SF	380,600	200	104,630 SF	282,500	200
INSTALLATION TOTALS (Lined Pond)		1,494,150	2,745		415,945	3,031		380,065	4,621
AVERAGE ANNUAL COSTS 4/									
UNLINED PONDS, 11%, 23 years		6,349			6,036			13,269	
Avg. Cost per AF, Crop Drain **		62			61			137	
LINED PONDS, 11%, 23 years		138,249			40,753			39,089	
Average Cost per AF, Crop Drain		1,355			412			403	

1/ Includes estimated electricity costs.
2/ Eucalyptus is irrigated to provide full needs plus leaching.
3/ Projected plant costs, without system from field to Regional plant.
4/ Regulation/tailwater pond and evaporation ponds built as two-cell complex.
NOTE: Costs are for all new construction. Existing facilities and site conditions and configuration may decrease or increase the costs.
Costs are based on 1987 materials and installation costs for Hanford area.


Boundary of Block -2640'
Install Perimeter Drain - 2640'-4"
Exist. Collector Drain
Sump & Pump 6' ØX15'; 3HP
EVAPORATION POND
Storage Vol. 31.5 A.F.
657'X657'
9.91 Ac.
Install New Collector Drain - 1220'-6"
"GROSS" ACRES - CROPLAND ≈ 150.0 ACRES
POND ≈ 10.0 ACRES

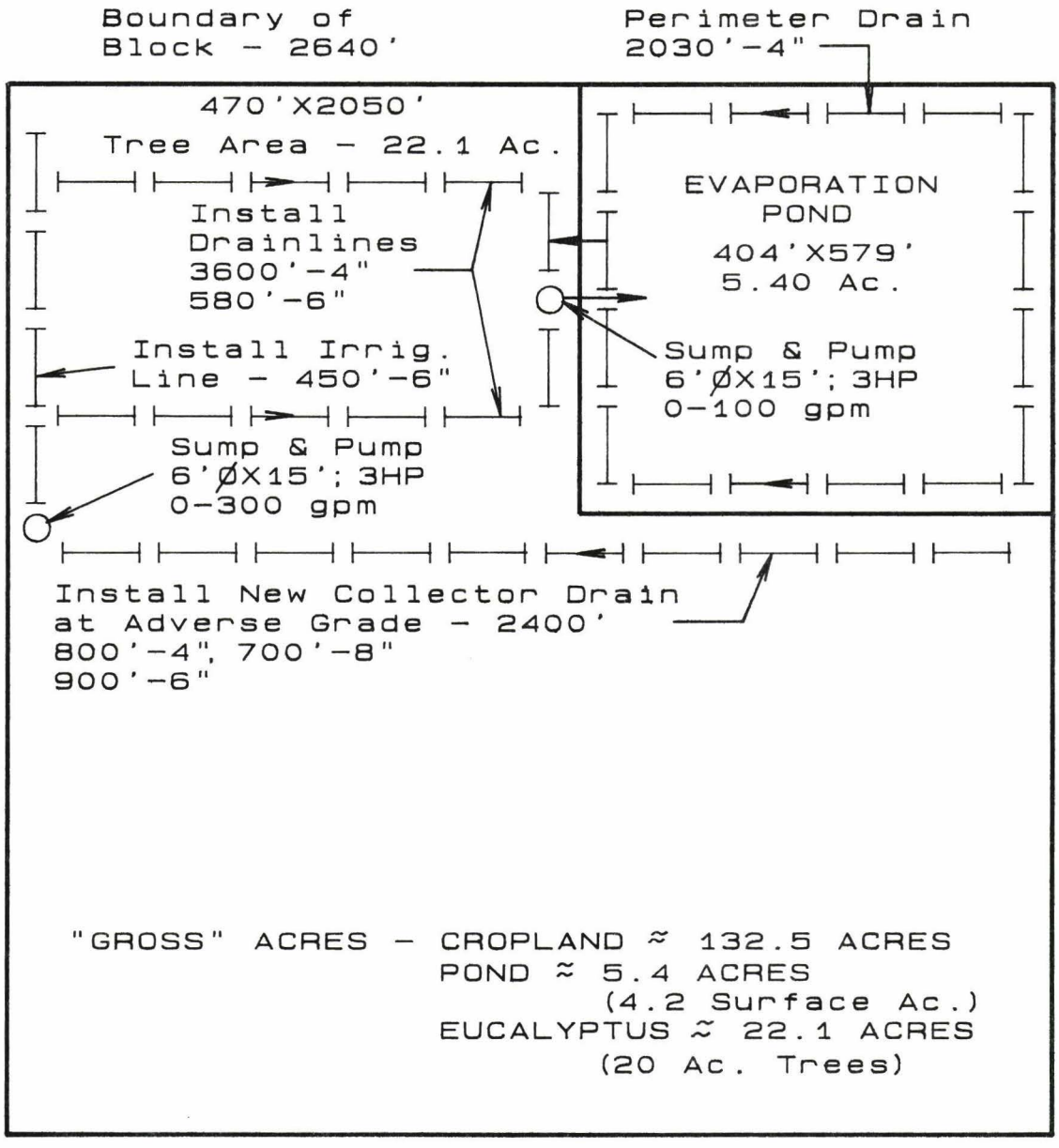
Evaporation Pond

8 Surface Acres at 2' Deep, Freeboard ≈ 2.0', Sludge Depth ≈ 0.5', Storage = 31.5 A.F., Inside Bottom = 578'X578', Excavation - Stripping and 1.25' Over Bottom.



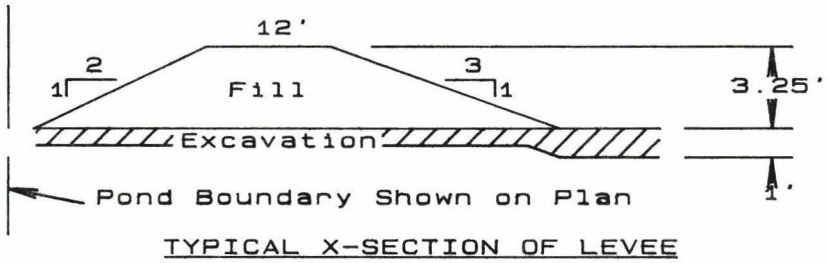
TYPICAL X-SECTION OF LEVEE

FIGURE D-1



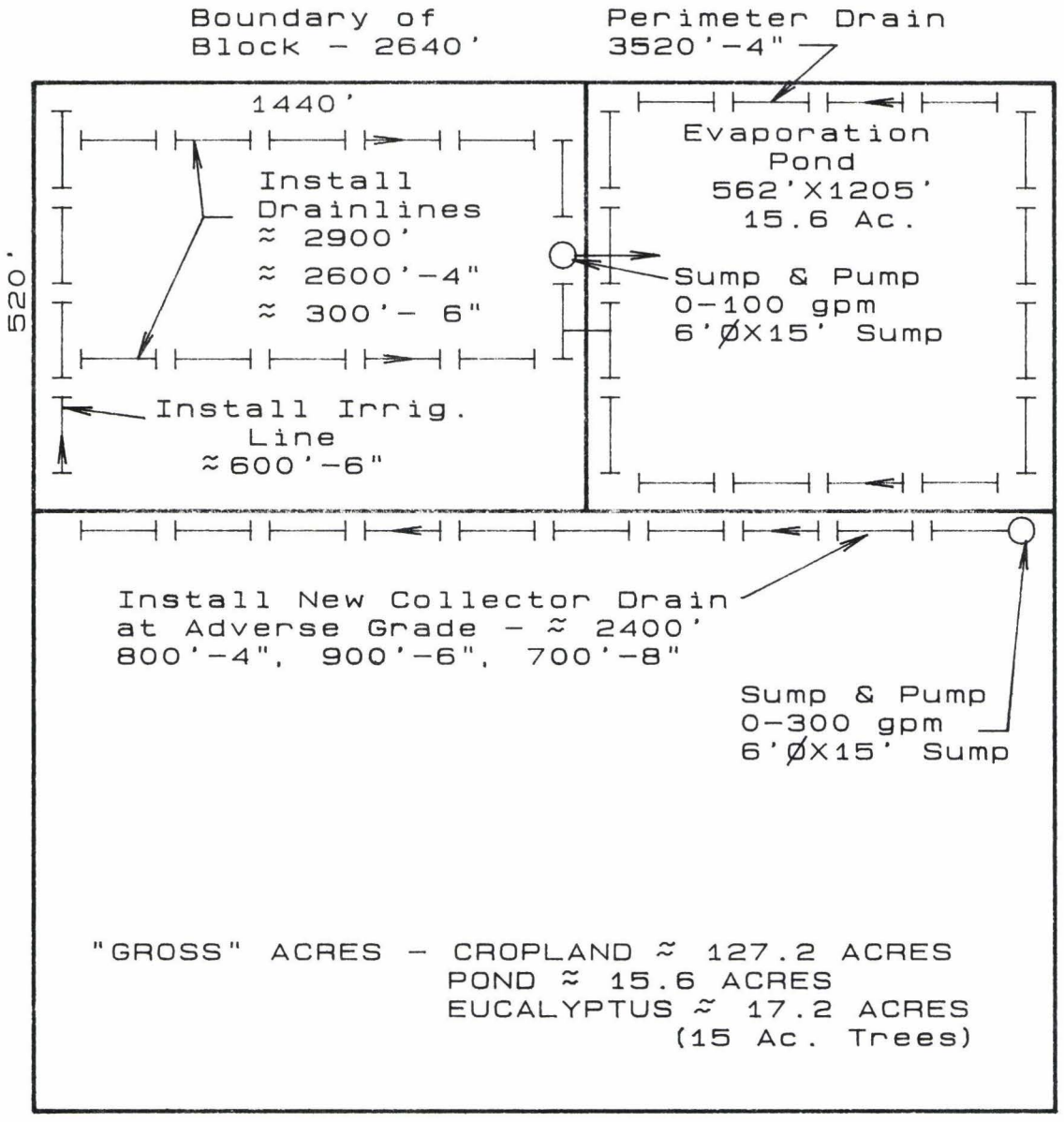
Evaporation Pond

4.2 Surface Acres at 1.5', Freeboard ≈ 2.0'
Approx. Depth =4.25', Sludge Depth ≈ 0.5',
Storage =8.6 Ac., Excav. Depth = 1.0',
Inside Bottom =351'X516'



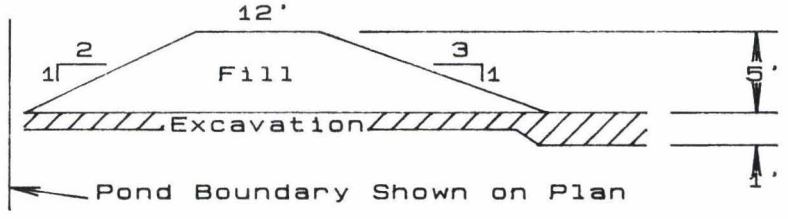
TYPICAL X-SECTION OF LEVEE

FIGURE D-2



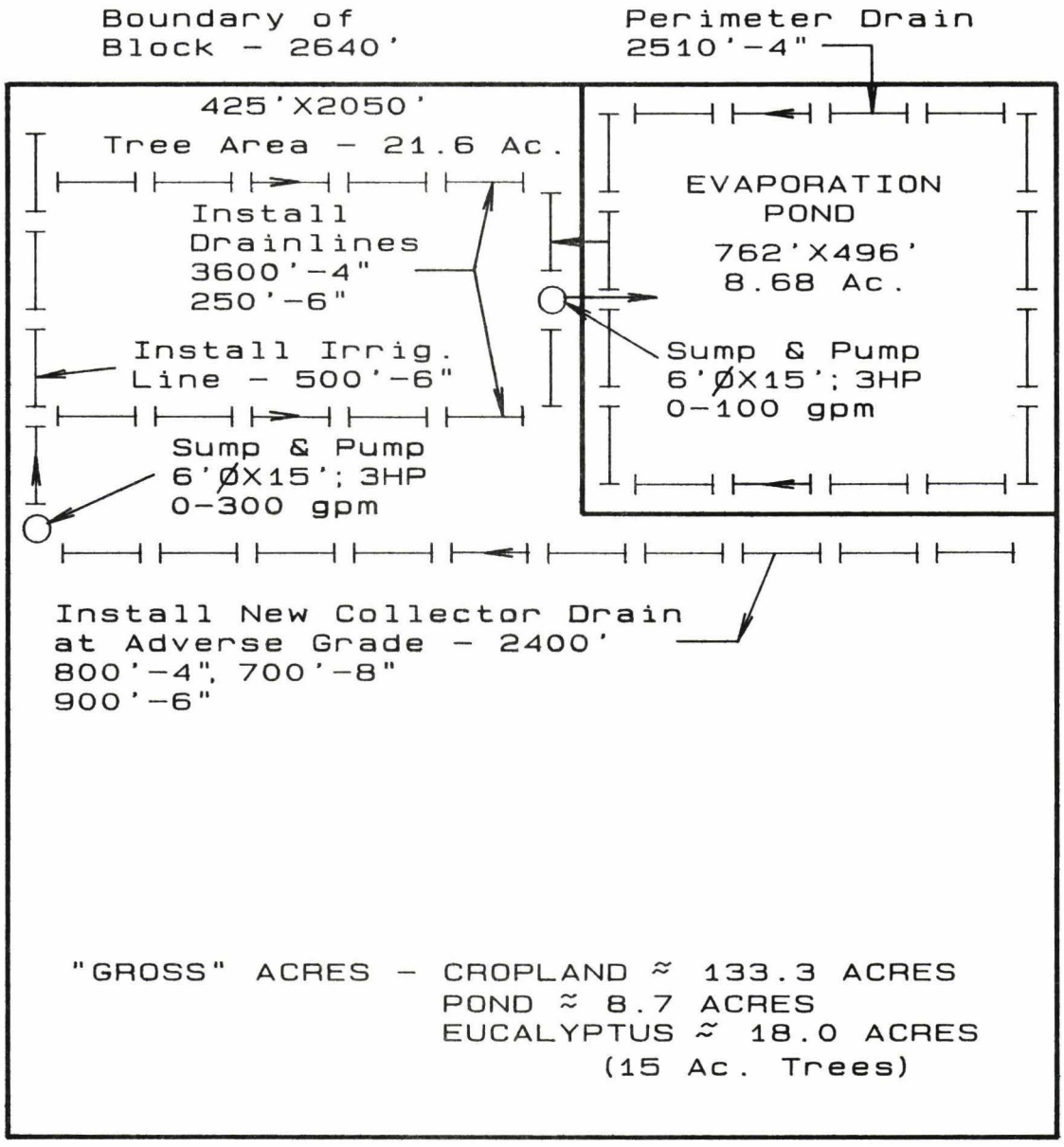
Evaporation Pond

13 Surface Acres at 3' Deep, Freeboard ≈ 2.0', Depth = 6.0', Sludge Depth ≈ 0.5', Storage = 44.5 A.F., Excav. Depth = 1.0', Inside Bottom = 482'X1115'.



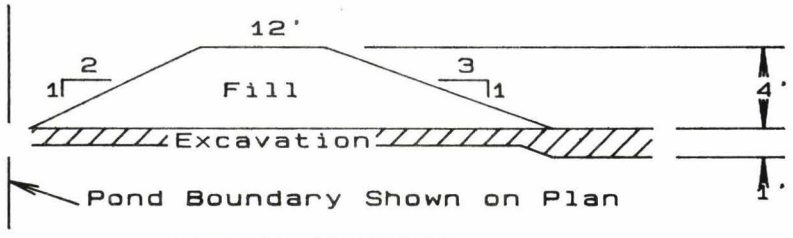
TYPICAL X-SECTION OF LEVEE

FIGURE D-3



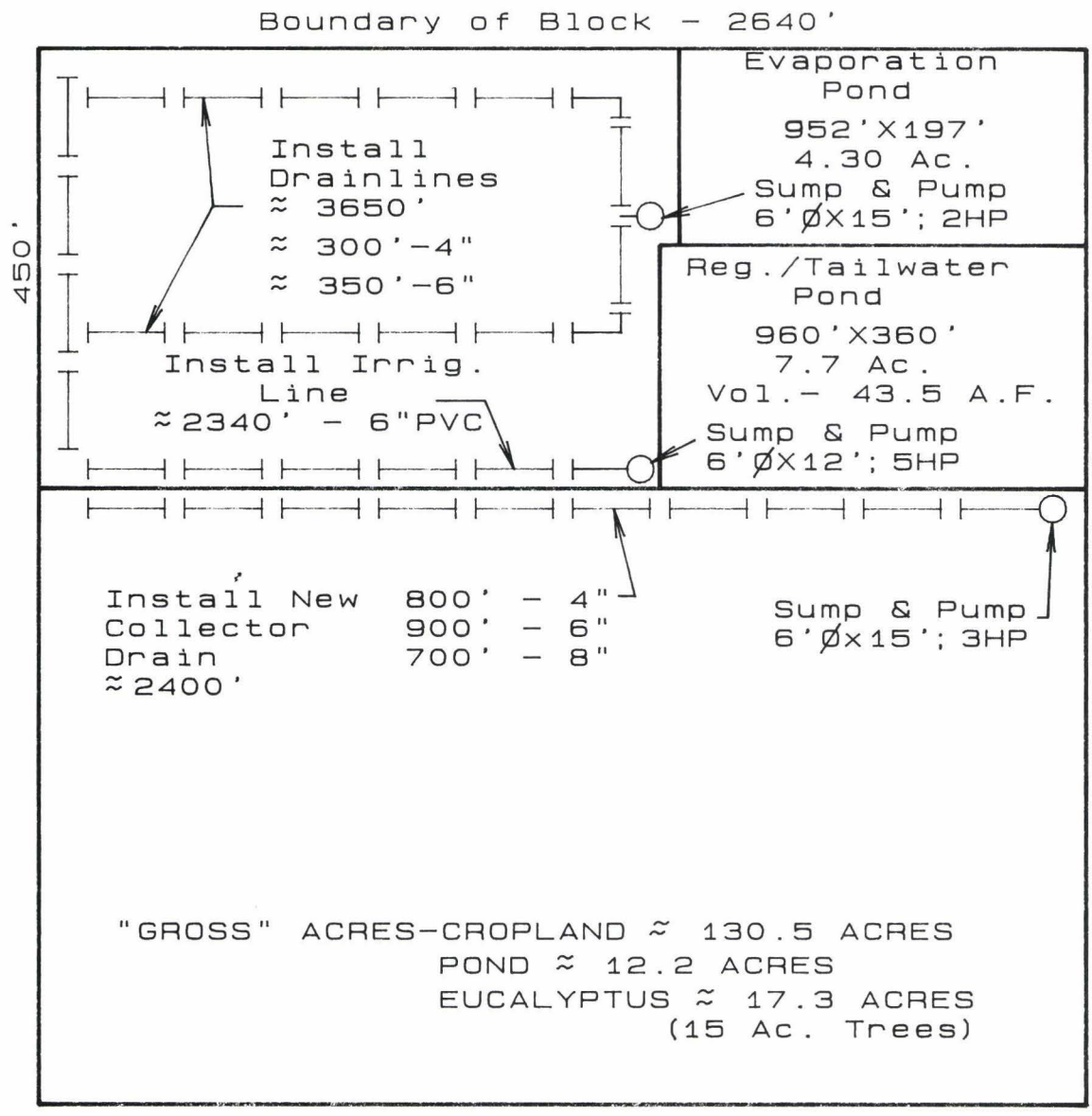
Evaporation Pond

7.0 Surface Acres at 1.5', Freeboard ≈ 2.0'
Approx. Depth = 5.0', Sludge Depth ≈ 0.5',
Storage = 21.4 A.F., Excav. Depth = 1.0',
Inside Bottom = 426'X692'.



TYPICAL X-SECTION OF LEVEE

FIGURE D-4

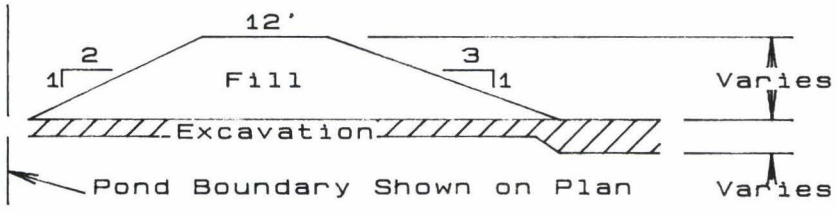


Evaporation Pond

3 Surface Acres at 2' Deep, Freeboard= 2.0' Depth = 4.0', Sludge depth = 0.5', Storage = 5.5 A.F., Excav. - Stripping Only, Inside Bottom = 888'X133'.

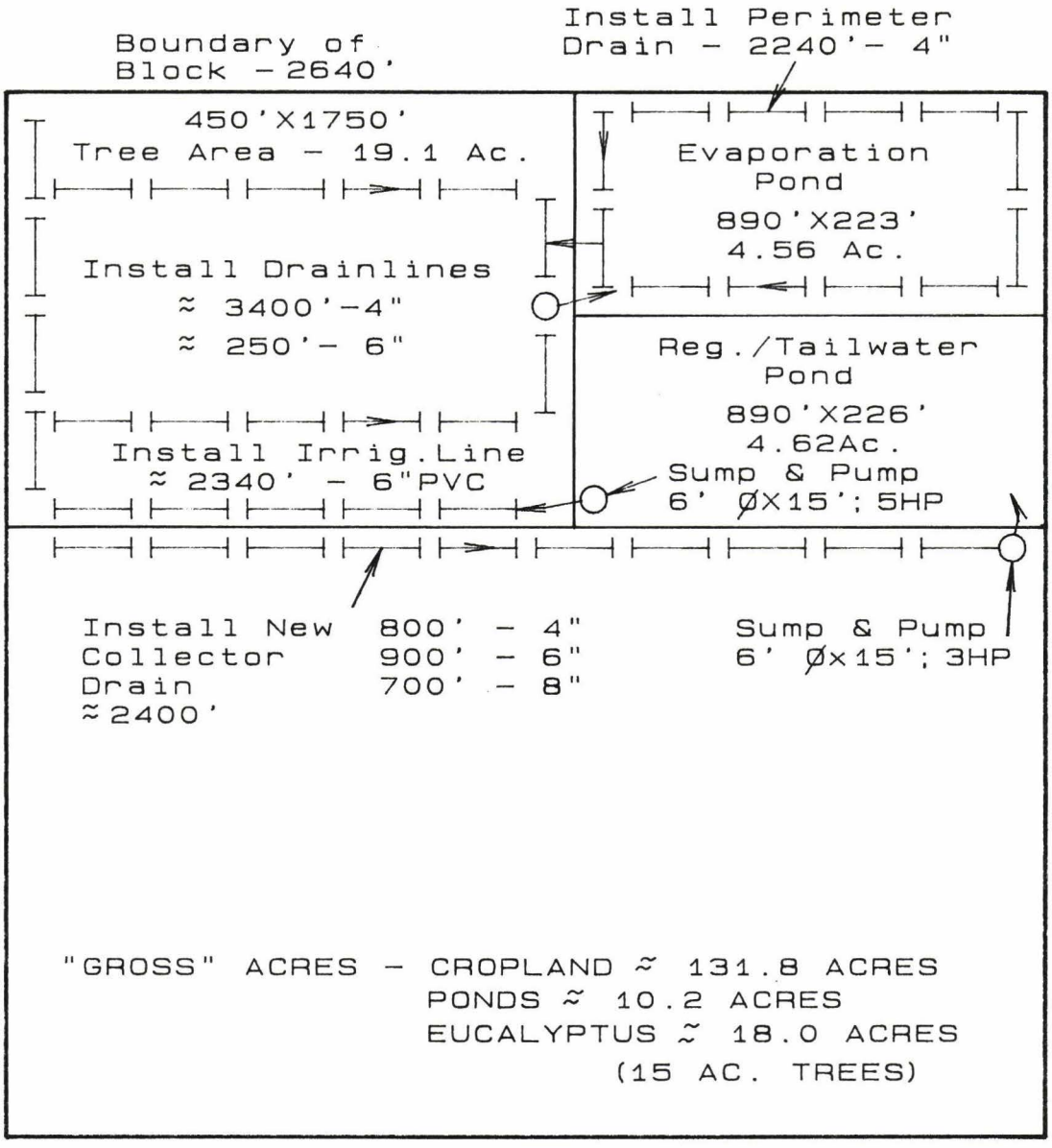
Regulation/Tailwater Pond

5.5 Surface Acres at 4' Deep, Freeboard = Depth = 10.0', Sludge Depth = 0.5', Storage = 43.5 A.F., Inside Bottom = 252'X852', 4.0' Over Bottom.



TYPICAL X-SECTION OF LEVEE

FIGURE D-5

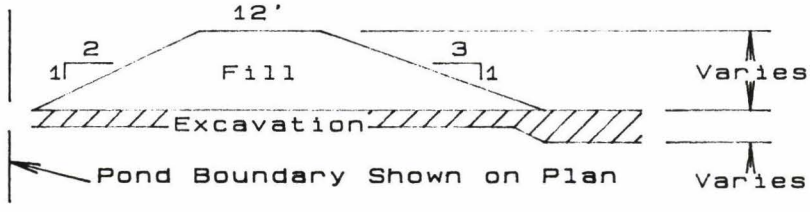


Evaporation Pond

3.5 Surface Acres at 1.5' Deep, Freeboard≈ 2.0', Appox. Depth = 4.0', Sludge Depth = 0.5', Storage ≈ 6.1 Ac., Excation - Stripping Only Inside Bottom = 838'X171'

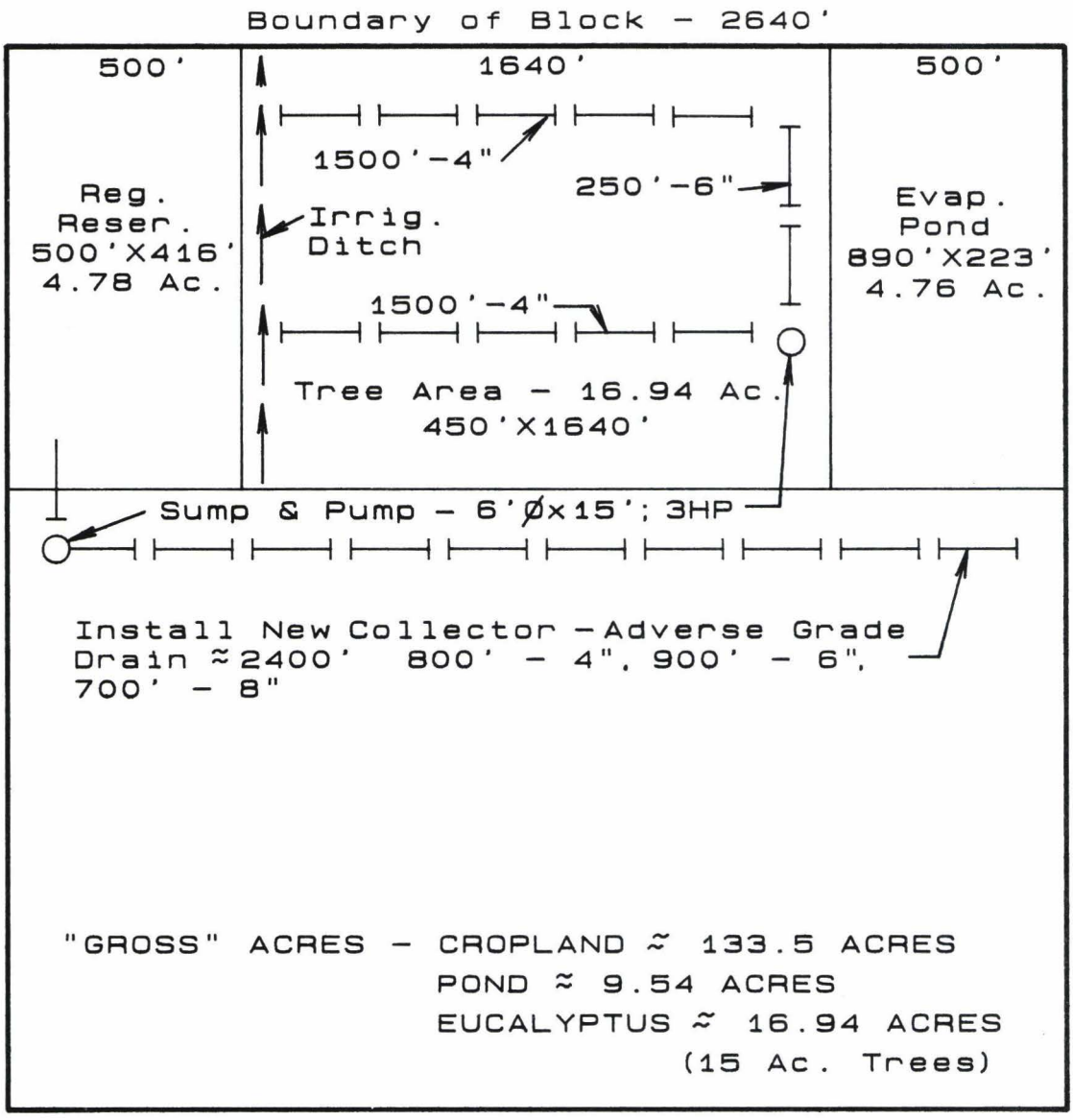
Regulation Reservoir/ Tailwater Pond

3 Surface Acres at 4' Deep, (Ground Surface) Freeboard ≈ 2.0', Approx. Depth = 8.0', Sludge Depth = 0.5', Storage = 17.4 Ac., Excavation Depth ≈ 4.25', Inside Bottom = 800'X138'.



TYPICAL X-SECTION OF LEVEE

FIGURE D-6

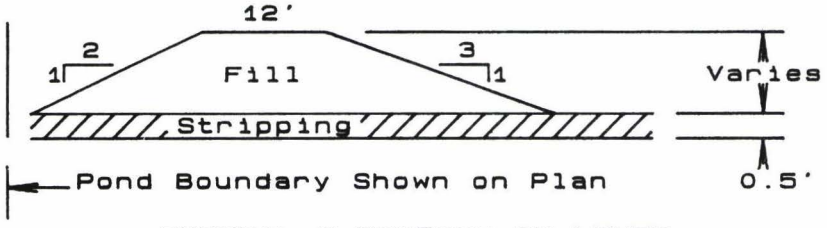


Evaporation Pond

3.5 Surface Acres at 2.0, Freeboard ≈ 2.0' Approx. Depth = 4.0', Sludge Depth = 0.5', Storage ≈ 4.76 Ac., Inside Bottom = 436'X 351', Stripping Excav. Only, Excav. from Tree Area.

Regulation Reservoir - (Above Ground)

3 Surface Acres at 3', Freeboard ≈ 2.0', Depth = 8.0' (Bottom Filled 2.0'to Allow Gravity Flow to Trees), Levee Height = 10.0', Storage = 4.78 Ac., Inside Bottom = 388'X304', Excavation from Tree Area to Construct Raised Bottom and Levees.



TYPICAL X-SECTION OF LEVEE

FIGURE D-7

REGIONAL DRAINAGE YIELD

For this study, the regional drainage yield is that part of shallow ground water that can be removed by drainage facilities. The shallow ground water making up the regional yield originates in the upper watersheds and is trapped and held near the ground surface by an underlying, confining clay layer. This shallow ground water moves downslope along the top of the clay layer.

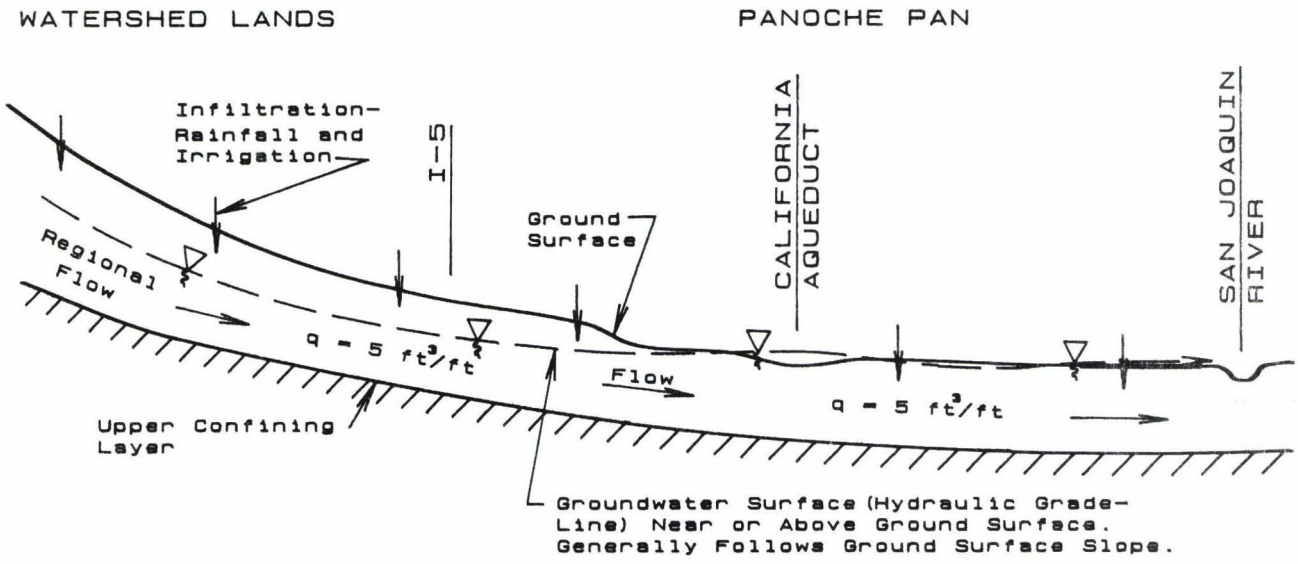
Shallow ground water moves downslope along a confining layer and the hydraulic grade line (approximate free water surface) is generally somewhat parallel to that layer. The elevation of the hydraulic grade line above the layer is dictated by the various and changing soil permeabilities and resulting changes in hydraulic head required to overcome friction and obstruction losses to move the water through the soil profile. As the hydraulic head increases, so does the elevation of the hydraulic grade line and the depth over the confining layer. If the hydraulic head losses are great and the hydraulic grade line loses less elevation than the loss in elevation of the overlying ground, the ground water intersects the surface and may become surface flow or form a swampy area, unless removed by vegetation or drainage. See the sketch, Figure D-8.

In agricultural areas overlying shallow ground water, drainage facilities are installed to lower the water table below the rooting zone. The drainage water removed includes regional flow (regional drainage yield), excess irrigation water and infiltrating rainfall. Regional flow is removed by successive drainlines until the flow volume has been reduced to that which requires a hydraulic grade line at or slightly above the bottoms of the drainlines. Irrigation water and rainfall that infiltrate are removed to the extent that they "mound" on the underlying "water table" and have a hydraulic gradient towards the drainlines. The rate of drainage yield to drainlines is determined by the hydraulic head above the line, the permeability of soil, the distance between drainlines, and the amount of free water in the soil prism being drained. See the sketch, Figure D-9.

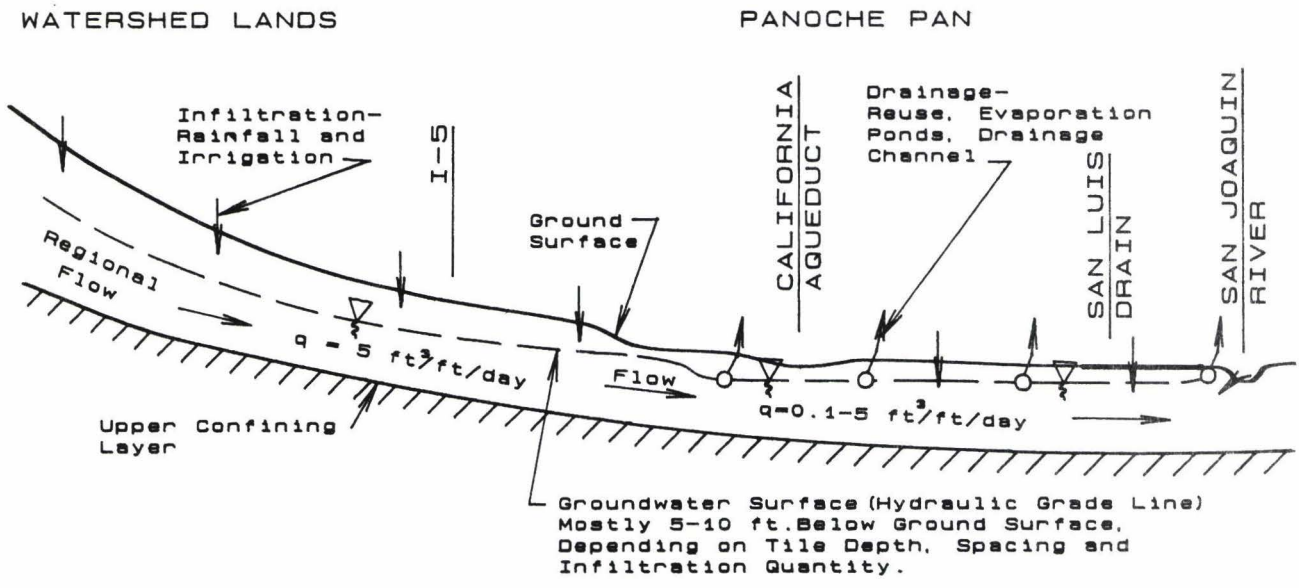
For this study, high regional drainage yield refers to that regional flow that can be removed by drainage in the upper reaches of the fan and near water bodies that can contribute to shallow ground water flows. Low regional drainage yields refer to the reaches of the drained agricultural area where most of the regional flow has been removed. In both "zones", infiltrating rainfall and irrigation water will also add to the drainage volume. Ranges of regional drainage yield can be estimated by using a proportion of the drained distance between the high and low yields. Figure D-10 is a map of the estimated areas of high and low regional drainage yields obtained from references describing studies done in the area.

The high regional drainage yield is 5 cubic feet per day per foot, and the low yield is 0.1 cubic foot per day per foot. The term "per foot" refers to a one-foot wide strip of the soil profile that extends from the soil surface to the confining layer and is perpendicular to the direction of flow. Drainage facilities may intercept all or part of the total regional flow and are usually designed as if they intercept all the flow, unless the flow depth is very deep compared to the drainage depth (not so in this study area). The regional drainage yields, in cubic feet per day per foot, are equivalent to about 8.4 AF/Ac/yr and 0.4 AF/Ac/yr, respectively, for drainage computations.

Other factors that may affect the volume of drainage to be expected are sand/gravel stringers, the extent of drained land surrounding the site, depth of drainage tile, irrigation efficiency, leaching volumes, rainfall volumes, consumptive use by vegetation, and evaporation. If sand/gravel stringers are encountered, the drainage yields may be substantially increased or decreased, depending on the water being carried by the stringer. Stringers will require individual site designs and will not reflect average drainage yields of other sites. The greater the extent of drained land surrounding the site, the more likely that drainage yields will approach those of irrigation and rainfall only. Conversely, the lesser the extent, the more likely that drainage yields will approach those of the high regional yield, plus irrigation and rainfall. Irrigation efficiency, leaching volumes, rainfall, evaporation and consumptive use can change the drainage volumes produced.



BEFORE DRAINAGE

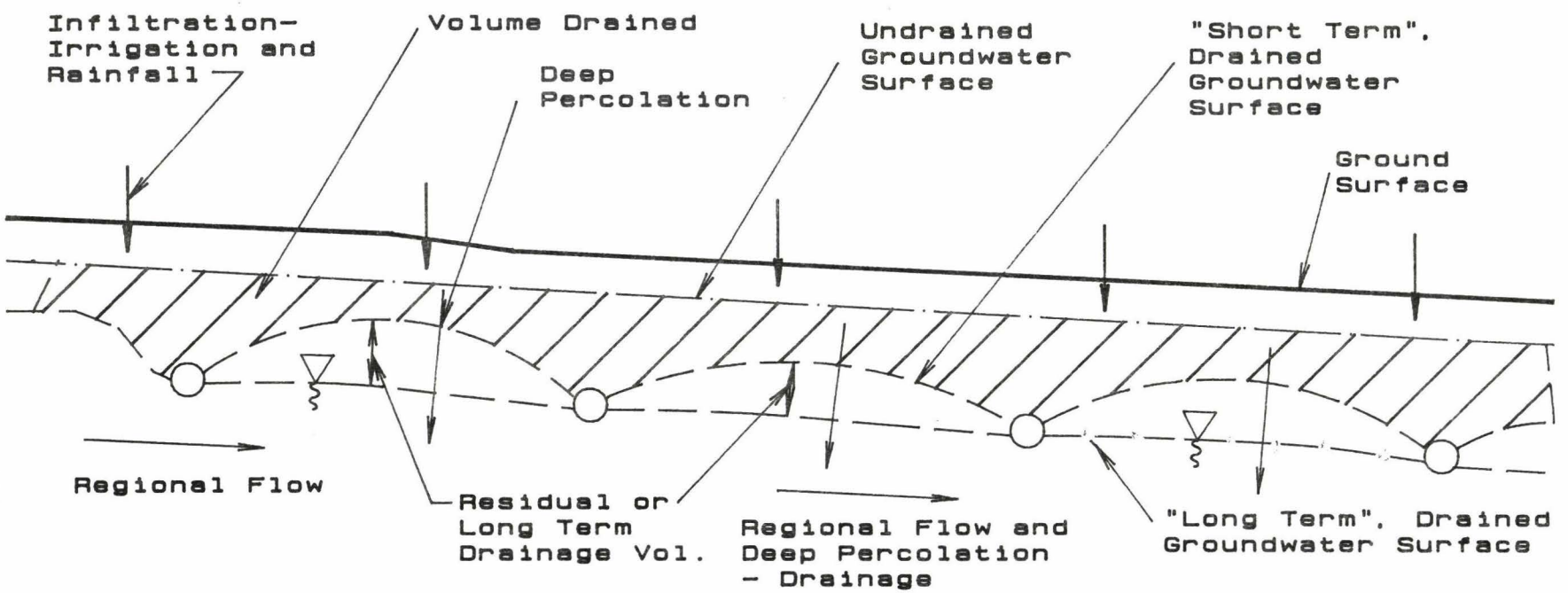


AFTER DRAINAGE

DIAGRAMIC SKETCH OF REGIONAL GROUNDWATER FLOW

FIGURE D-8

DIAGRAMATIC SKETCH OF LOCAL GROUNDWATER FLOW

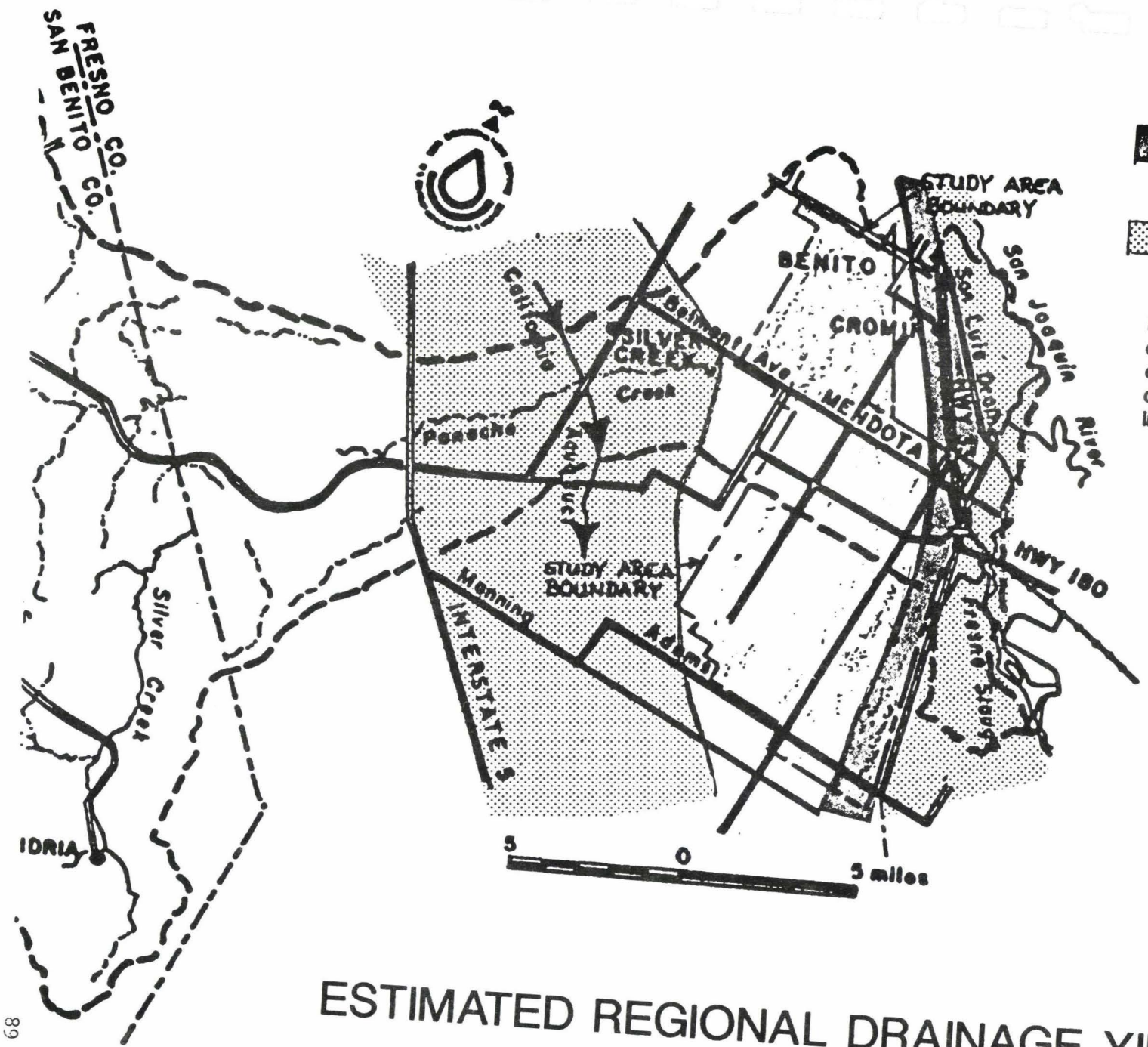


The "Long Term" Drained Groundwater Surface Can be Theoretically Obtained if Only Regional Flow Exists and there is Little or No Infiltration in the Area Drained.

The "Short Term" Drained Groundwater Surface is the One that Normally Exists, because Infiltration Occurs in the Area Drained.

The Drainage Volume Includes that Portion of Regional Flow Above the Drainage Springline and Infiltrates from the Surface, Less the Residual Volume and Deep Percolation. For Practical Purposes, Deep Percolation is Assumed to Regenerate Regional Flow and Increase that Volume Interdicted by Downslope Drainlines.

FIGURE D-9



Approximate areas where low regional drainage yields can be expected (0.001 in./day/acre)

Approximate areas where high regional drainage yields can be expected (0.023 in./day/acre)

Regional drainage yields in this area decrease as total drained acres increase or as the distance between the upper confining layer and ground surface increases.

ESTIMATED REGIONAL DRAINAGE YIELDS

Panoche Creek Salinity Study

FIGURE D-10

ASSUMPTIONS, RISKS AND UNCERTAINTIES

Assumptions were made when there was a shortage of data or when there was a wide range and it became reasonable to use average values in designs or engineering findings. Risks and uncertainties are the possible effects that may occur when using assumptions. These effects may considerably change the results of the designs or findings made using the assumptions.

1. Designs were made for drainage yields that would occur for soils and crop rotations in the study area, normal rainfall and evaporation for the general area, and for high and low regional drainage yields.

   Average or normal rainfall and evaporation were obtained from the CIMIS station nearby at Hanford. Rainfall and evaporation change considerably from year to year. Rainfall above normal for any given month (or more) will increase drainage yields. Cooler weather than normal will reduce the rate of evaporation, requiring a larger storage volume in ponds. NOTE: evaporation ponds should not be allowed to dry out. The salts in dry ponds are considered by the Water Quality Control Board to be a hazardous waste that needs to be removed .

   High regional yield occurs at the upper and lower fringes of the drained areas and along the upper slopes of the Panoche Fan to just below the California Aqueduct. Low regional yield occurs towards the lower end of the drained area, just above the San Luis Drain. High regional yield is assumed to occur between the Drain and the San Joaquin River because of backflow from the river. Regional flows will decrease in the downslope direction, between the high and low yields, as drainage facilities remove free water. Regional yields can also vary along the ground water flow front, most frequently because of changes in elevation and in soil permeability.

   The crop rotation used for the drainage designs were cotton-cotton-grain. This design would be adequate for all the crops normally grown in the area, except alfalfa. Fully irrigated alfalfa would require about one-fourth more storage capacity in ponds for winter season drainage. Soil information was obtained from SCS soil surveys of the area.

2. Drainage yields do not account for gravel or sand stringers that may be crossed or intercepted by drainlines. If stringers are crossed or intercepted during excavation for drainlines, special designs will be needed to offset the effects. The effects may include excessive free water from the stringer to be drained or in loss of field drain water to the stringer (probably of greater concern to the downslope neighbors than to the installer).

3. Tailwater is assumed to be immediately removed from the fields and recirculated. No additional drainage yield is included for tailwater percolation from temporary pond storage. If the tailwater pond is located near a drain line, the amount of drainage intercepted by that line will be considerably increased. Tailwater pond percolation would require a larger evaporation pond storage volume and evaporation area. This effect is most likely incremental, but may severely affect facilities constructed to minimum anticipated volumes.

4. The leaching fraction (additional irrigation water) is assumed to be 15 percent for crops (per Westlands Water District and grower interviews) and 10 percent for trees. These fractions should maintain salinity in the root zone soils at satisfactory levels for crop growth, including germination. A 70 percent application efficiency has been assumed and used in determining the salinity concentration levels. If the leaching fraction or irrigation efficiency change, then the amount of drainage will also change. If leaching is reduced, soil salinity may increase. A 5 percent leaching fraction can be used for cotton if the irrigation is uniform, but a leaching cycle may be needed each five years to remove accumulated soil salts. If irrigation efficiency is increased (could be costly), the drainage quantity may be reduced without increasing soil salinity.

5. All installations are assumed to be new. No cost or installation reductions have been made for existing facilities that may be useable or used. Use or abandonment of existing facilities or equipment may change the net costs of installation considerably. Costs may also be considerably reduced if suitable construction materials, especially clay for lining, are available on-site.

6. Layouts for the designs were made for the "best" apparent efficiency. Existing layouts and facilities may require changes to those shown in order to reach the best efficiency for the site. Also, other layouts may be equally or more efficient, depending on operation and management. Each change would alter the net costs presented by the examples and would require analysis to determine actual cost effectiveness.

7. Drain water is not expected to be co-mingled with fresh water in regulation reservoirs. This practice will reduce the quality of irrigation waters and will make salinity management very difficult. Drain water is used on cropland only when the quality is acceptable for reuse and mixing at the irrigation site (generally when the TDS is less than 6,000 mg/l).

8. Crops and trees are assumed to be fully irrigated, plus leaching, at the times they need irrigation. If less irrigation is used, the volume of drainage will decrease. If

more irrigation or a lower irrigation efficiency is used, the volume of drainage will increase.

9. Evaporation, rainfall and ET rates used were from averaged data collected at the CIMIS station near Hanford. If these rates are different, either because of normal variation or from topographical variation, then the rates used in the computations will change and the irrigation needs and the drainage volumes will change. These changes are not expected to be unmanageable by the proposed facilities, but will require site-by-site designs. The annual rates may vary substantially from the average rates 80 percent of the time, causing the observed volumes or rates to be less than or exceed the design volumes or rates that percent of the time.

10. The ET rate for eucalyptus is based on average rates of ET vs. pan evaporation obtained from recent agroforestry publications. As more data becomes available from California test plots, the ET rates will change and will be based on more representative data. The present rate is 90 percent of pan evaporation. Some new data indicates that a larger ET may be useable in semi-arid climates. The higher the ET, the less plantation needed to use drain water, and, of course, vice versa.

11. The cropping dates for the rotation used to estimate drainage yields were the averages used in the general area. If the planting dates are substantially different, for management or weather, the drainage yields will vary. The total drainage yield will likely be about the same, but the peak volume may change both in time of year and peak flow. Earlier plantings will generally reduce spring and summer flows and increase winter flows. Later plantings will require more irrigation and will generally increase spring and summer flows and decrease winter flows.

12. The pre-irrigation was assumed to be no more than the required four inches. If larger amounts are used, the drainage volumes will increase substantially. The storage requirements in the evaporation pond or the storage pond will also be increased.

13. Salts, removed from evaporation ponds in the fall as needed for environmental or capacity purposes, can be disposed of as Class II hazardous wastes. Salt accumulations for longer than three years may cause wildlife toxicity and will reduce pond evaporation rates.

14. Present pilot plant costs to treat drainwater range from $675 to $1,100 per AF. It has been estimated that a regional plant through economics of scale, can reduce treatment costs to $100-$200 per AF. These lower costs would make regional plants competitive with on-farm systems. A collector pipe system for a regional plant is estimated to have a minimum

annual cost of $12-$15/AF, but any required pumping would increase costs.

15. Tree roots are not expected to enter drainlines 10-feet away from the trunk line because of full irrigation and a high water table. If a low water table or partial irrigation (groundwater use) occur, 1 1/2 the full growth canopy radius should be used.

16. Storage of excess drainwater and runoff in and on the tree plantation soils is assumed to not cause excessive percolation from the site. Monitoring of water leaving the plantation area may be needed. If high salinity drainwater is leaving, additional drains and a regulating/tailwater pond and /or larger evaporation pond will be needed.

APPENDIX E

ANNOTATED BIBLIOGRAPHY

APPENDIX E. Annotated Bibliography

This contains a listing of the reference material used to formulate the recommendations of the report. Where a specific part of the reference was useful for this report, it is noted after the citation. If the reference was useful for general background, then a general description of the reference contents is given after the citation.

Biddiscombe, E.F.; A.L. Rogers; E.A.N. Greenwood; and E.S. DeBoer. 1981. "Establishment and Early Growth of Species in Farm Plantations Near Salt Seeps," Aust. Jour. of Ecol., 6:383-389.

The comparative success of 28 species in establishment and early growth, when grown on or near saline seeps, is described. Chloride content in the top meter of soil was generally less than 300 mg/kg, and perched water within seep areas contained chloride up to 2000 mg/l. Eucalyptus wandoo, E. camaldulensis and Casuarina obesa survived well at all locations. E. globulus, E. camaldulensis, E. occidentalis and E. cladocalyx var. nana exhibited vigorous early growth and were judged to be quicker than other tested species for reducing flow from catchments by using more water than pasture or crops in the same habitat.

Blake, T.J. 1981. "Salt Tolerance of Eucalypt Species Grown in Saline Solution Culture," Aust. For. Res., 11:179-183.

Fifty-two species and subspecies of Eucalypts were tested for salt tolerance by growing seedlings in nutrient solution, then progressively adding salt until 50 percent mortality occurred. Any species able to survive greater than 300 mM NaCl concentrations was judged salt tolerant. Eucalyptus camaldulensis exhibited high salt tolerance (400 mM NaCl).

Clemens, J.; L.C. Campbell; and S. Nurisjah. 1983. "Growth and Mineral Ion Concentrations of Casuarina Species Under Saline Conditions," Aust. Jour. Bot. 31:1-9.

Eleven casuarina species were tested for salinity tolerance at germination and/or as seedlings. Seed germination showed greater sensitivity to NaCl than did seedling survival. Casuarina cunninghamiana and C. glauca were among the more salt tolerant species tested. The more NaCl resistant species had both the ability to exclude ions and a lesser component of ion compartmentation in the root.

DeBell, D.S.; C.D. Whitesell; and T.H. Schubert. 1985. "Mixed Plantations of Eucalyptus and Leguminous Trees Enhance Biomass Production," Res. Paper PSW-175, USDA Forest Service, PSWF&RES, Berkeley, CA.

Study findings suggest that where there are low levels of available N growth rates of some eucalyptus species can be enhanced substantially by planting in mixture with nitrogen fixing trees. Total biomass was much greater in the mixed plantations than in pure eucalyptus plantations.

Donaldson, D.R.; J.K. Hasey; W.B. Davis. 1983. "Eucalyptus Out-Perform Other Species in Salty, Flooded Soils," California Agriculture, Sept-Oct.

Over 100 tree and shrub species were evaluated for their ability to grow in saline, frequently flooded soils during a 10-year period along the Napa River in northern California. The ground water table was within 30 inches of the surface for seven months of the year and ranged from 1.6 to 46.7 mS/cm EC. Seventeen eucalyptus species, including E. camaldulensis, survived with visually acceptable growth. Twelve other mixed species, including Pinus brutia and Populus euphratica, survived, but showed severe salt injury. The remaining species, including Pinus eldarica, were either dead or very severely stunted after the ten-year test.

El-Lakany, M.H. and E.J. Luard. 1982. "Comparative Salt Tolerance of Selected Casuarina Species," Aust. For. Res., 13:11-20.

Ten species of Casuarina from both Egypt and Australia were grown in saline solutions ranging from 0 to 550 mmol/dm3 NaCl. C. glauca was judged most tolerant and was recommended for afforestation and reforestation of salt-affected land. C. obesa, C. cunninghamiana, C. equisetifolia var. incana all survived relatively high salt concentrations and would be valuable in some saline areas. The potential for nitrogen fixation was also mentioned.

Elmore, C.L. 1983. "Vegetation Management in Eucalyptus, Proceedings at a Workshop on Eucalyptus in California," Gen. Tech. Rep. PSW-69, USDA Forest Service, Pacific Southwest Forest & Range Experiment Station, Berkeley, CA.

Weed control is recommended for at least two years and should be started prior to planting. Safe pre-emergence herbicides include oryzalin, napropamide, oxadiazon, linuron and to a lesser degree simazine, atrazine and diuron. Effective post-emergence herbicides include glyphosate, amino triasole and paraquat. Combinations of mechanical and chemical weed control help allow maximum plantation establishment and growth.

Florence, R.G. 1986. "Cultural Problems of Eucalyptus as Exotics," Commonwealth For., Rev. 65(2).

A literature review concludes that the wide range of genetic material in eucalyptus has not been adequately tapped. Competition, water use and nutrient cycling is discussed. Observed effects of eucalyptus on soil condition might best be attributed to strong competition for water and nutrients. Where trees replaced grasslands or low vegetation, a reduction in water yield should be expected. High rates of wood production will be matched by high rates of water use when eucalyptus is used as an exotic. In natural stands, eucalypt forest uses water conservatively much the same as coniferous forests under comparable energy inputs and leaf area indices.

Greenwood, E.A.N.; J.D. Beresford; J.R. Bartle; and R.J.W. Barron. 1982. "Evaporation From Vegetation in Landscapes Developing Secondary Salinity Using the Ventilated - Chamber Technique," Jour. of Hydrology, 58:357-366.

Daily evaporation from five regenerating trees ranging in leaf area from 1 to 70 square meters, and from areas of pasture near them, was periodically measured over a year. Evaporation from the trees was about twice that for pasture. The greater uptake of water by trees was ascribed to the extension of their roots beyond the area of their canopies and to a greater depth than the roots of the annual pasture.

Greig, P.J. 1981. "Tree Removals and Saline Seepage in Victorian Catchments: Some Hydrologic and Economic Results, in Eucalyptus Dieback in Forests and Woodlands," Proceedings of a Conference CSIRO Div. of For. Res. Canberra; Old, K.M. et al Ed.

The relationship between tree clearing and stream salinity was examined. Fifty-eight percent of the variation in salinity was explained by the proportion of forest cover (i.e. the greater the forest cover, the lower the measured salinity). This, along with the percentage of watershed with sedimentary bedrock and the average annual precipitation, explained a total of 71 percent of the salinity variation.

Hallsworth, E.G. 1981. "The Use of Saline Groundwater in Arid Areas," Exp. Agric., Vol. 17, pgs. 145-147.

Trickle irrigation using saline water up to an equivalent of 16,000 ppm (sea water being approximately 35,000 ppm) was used to establish and maintain Casuarina glauca and Eucalyptus camaldulensis windbreaks. Growth at the higher salinity levels was severely reduced, but high enough for stabilization and wind protection purposes.

Imam, M.El.S. and I.A. Heikal. 1972. "A Comparative Study on the Rate of Growth of Casuaria Spp and Eucalyptus camaldulensis and Its Yield on Sandy Soil Irrigated by Sewage Water at Gabal El Asfar," Agricultural Research Review, Egypt, Vol. 50:4.

Contains a short review of literature concerning Casuarina spp and E. camaldulensis in North Africa. The paper recommends Casuarina glauca be included on saline sites along with E. camaldulensis. The casuarina is a better windbreak tree and provides protection to the faster growing eucalyptus.

Ingham, N.D. 1908. "Eucalyptus in California," U.C. Agricultural Experiment Station, Berkeley, CA, Bulletin 196.

The bulletin notes that nearly 100 species of eucalyptus were identified growing in California, with some groves of

considerable size which were 40 to 50 years old (i.e. established circa 1860). The bulletin cautioned that relatively cheap natural gas and electricity would limit plantation harvest for fuelwood, and gives some assessment of hardwood value for commercial uses. The author recommended planting at 6'x 6' spacing (1,210 trees/acre), then thinning up to 50 percent at the end of the first year. Considerable information is provided on the propagation and culture of the most successful species. Eucalyptus globulus was recommended as the best all around species for California, and notes that for fuelwood purposes, E. viminalis is also a rapid grower.

Jain, B.L.; R.S. Goyal; K.D. Muthana. 1983. "Performance of Some Tree Species in Relation to Irrigation With Saline Waters," Annals of Arid Zone, 22(3), 233-238.

A eucalyptus hybrid was included in a salinity tolerance test planting which was irrigated with water having an EC of 2.7, 6.0, and 9.0 mS/cm. The eucalyptus had a 25 to 30 percent reduction of both height and diameter growth at EC's of 6 and 9, compared to the EC of 2.7.

Karschon, R. and Y. Zohar. 1975. "Effects of Flooding and of Irrigation Water Salinity on Eucalyptus camaldulensis From Three Seed Sources," Div. of Forestry, Agricultural Research Organization, Israel Leaflet No. 54.

The study determined differences in response to flooding with water containing sodium chloride up to 4,500 ppm on 8 month old seedlings from Lake Albacutya (Vict:), Katherine (N.T.) and Wyndham (W.A.). Lake Albacutya showed the best tolerance of the sources tested.

King, J.P. and S.L. Krugman. 1980. "Tests of 36 Eucalyptus Species in Northern California," USDA-FS, PSWF&RES, Berkeley, CA, Research Paper PSW-152.

Australian foresters selected 36 eucalyptus species on the basis of potential cold-hardiness and tree form, and provided general seed collections for field trials at Concord, CA. The trials were subjected to both moisture stress (irrigation) and freezing temperatures. Nine selected species failed outright (E. brockwayi, delegatensis, diversicolor, dundasi, gomphocephala, polycarpa, redunca var. elata, torquata, calophylla). Three species were eliminated by repeated frosts (E. oleosa, robertsoni, salmonophloia). Nine species suffered continual mortality due to general lack of adaptation to climatic conditions (E. andrewsi, fastigata, niphophila, obliqua, pauciflora, radiata, regnans, stellulata, transcontinentalis). Eight species showed good survival but slow growth (E. behriana, coccifera, fruticetorum, melliodora, polyanthemos, resinifera, robusta, sideroxylon). Seven species had very good survival and growth (E. camaldulensis, dalrympleana, glaucescens, grandis, nitens, ovata, viminalis).

Kolar, M. 1963. "Financial and Timber Yields of Eucalyptus camaldulensis Dehn. Over Six Rotations," Contributions on Eucalypts in Israel II.

The Hadera Forest, established around 1900, occupied about 87 ha., and had been harvested up to six times. Average mai was 11 m3/ha/yr with mean annual increments of up to 19 m3/ha/yr reported. The original planting density was approximately 2,000 trees/ha., and was currently 800-1,000 t/ha.

Mariane, E.O.; W.A. Wood; P.C. Kouchoukos; and M.B. Minton. 1978. "The Eucalyptus Energy Farm: Feasibility Study and Demonstration," U.S. Department of Energy, Washington, D.C.

Notes the high potential of eucalyptus plantations to produce biomass for energy generation, and California as a suitable area for plantation establishment. Forty-five species were identified as having potential for use in California.

Mathur, N.K. and A.K. Sharma. 1984. "Eucalyptus in Reclamation of Saline and Alkaline Soils in India," Indian Forester, Vol. 110, No. 1, pg. 9-15.

Adaptability trials were carried out on two different sites. E. melanophloia, E. tereticornis, E. terminalis, and E. camaldulensis proved to be most promising species and were recommended for large-scale trials. Soil amendments (gypsum and manure) were also recommended. Eucalypts were considered superior to other trees because of their greater utility for wood and fuelwood, deep root system, and low attractiveness to wildlife and cattle for forage.

Merwin, M. L. 1987. "A Review of the Potential for Mitigating Secondary Soil Salinity by Tree Planting," International Tree Crops Institute USA, Inc., Davis, CA.

A literature review of 171 references relevant to salinity and its management worldwide, with an emphasis on California agriculture. Several case studies are presented to illustrate how the dual problem of soil salinity in shallow water table areas can be approached. The author concludes that trees may be used as part of an integrated salinity control strategy incorporating agronomic, mechanical and biological techniques. Tree planting alone will not be an effective solution to salinity and water table problems. Long-term salinity management depends on changes in agricultural practices to restore hydrologic balance and conserve irrigation water. Trees can play a supporting role in the maintenance of moderate salinity levels, but their value in discharge or irrigated situations is less certain.

Metcalf, W. 1924. "Growth of Eucalyptus in California Plantations," U.S. Agricultural Experiment Station, Berkeley, CA, Bulletin No. 380.

Reported between 40 and 50 thousand acres planted with eucalyptus, about 82 percent in blue gum (E. globulus globulus). The bulletin gives location, age, trees/acre, percent survival, average tree size, volume/acre, mean annual growth, and soil of the plantations inventoried. Utilization of eucalyptus wood is described. A yield estimate for blue gum on three site classifications is also provided with yields ranging from 2.3 to 6.8 cords/acre/year (ave. 3.02 c/a/yr.). A spacing on good sites of 8'x 8' for lumber production and 7'x 7' for cordwood production is recommended (no irrigation after establishment).

Morris, J.D. 1984. "Establishment of Trees and Shrubs on a Saline Site Using Drip Irrigation," Aust. For., 47(4).

A field trial was established on saline sodic clay soil with highly saline ground water within 2 meters of the surface. High mortality occurred due to salinity, frost and other site factors. Eucalyptus camaldulensis was the most successful of 22 species planted, in terms of both survival and height growth. Water use of E. camaldulensis was similar to a non-saline site and was apparently unaffected by the salt levels tested.

Morris, J.D. and L.A.J. Thomson. 1983. "The Role of Trees in Dryland Salinity Control," Proc. R. Soc. Vict., Vol. 95, No. 3.

The potential of some trees to control salting by using more water than crops or pasture on an annual basis and to draw it from deeper in the soil profile is discussed. Rooting depth of trees was conservatively estimated as 15 to 20 meters, where conditions allow, and salt tolerance to 12,000 ppm of total dissolved solids. E. camaldulensis and E. occidentalis were suggested as useful species where saline ground water is present. In general, trees were recommended as part of a balanced program of agriculture and agroforestry. The most effective method is to control ground water recharge and plant trees in small woodlots on marginal land, windbreaks, along roads or around homesteads.

Rinehart, J.A. and R.B. Standiford. 1984. "Blue Gum Plantations Analyzed For Economic Return," California Agriculture, May-June.

Ninety-six blue gum stands measured in 1924 by Metcalf were analyzed to develop a growth model for California. The economic and biological assumptions made for the model are described, and typical output tables are included. Table 2 gives maximized mean annual increment for a medium quality site (i.e. 10-year Site Index 85) at 5.27 cords/acre/year

with a planting density of 1,210 trees/acre and a rotation length of 11 years.

Rogers, A.L. 1985. "Foliar Salt in Eucalyptus Species," Aust. For. Res., Vol. 15.

Foliar salt in selected salt-tolerant eucalyptus species grown on one non-saline site and four saline sites in western Australia were recorded over a five-year period. Average sodium concentrations ranged from 0.15 mg/g dry matter in E. melliodora to 12.1 mg/g in E. astringens, and average chloride concentrations from 3.3 mg/g in E. rudis to 18.1 mg/g in E. astringens. Eucalyptus camaldulensis and E. melliodora had similar concentrations of sodium and chloride on both saline and non-saline sites. The very low sodium concentrations of sodium in both of the species indicated that exclusion is very efficient. Foliar analysis was not found to be a reliable indicator of salt tolerance under field conditions. Mortality was recorded for E.astringens, E.globulus, E.kondininensis, E.maculata, E.patens, E.robusta, and E.wandoo at one or more of the sites, and appeared to be due to prolonged waterlogging with saline ground water.

Sachs, R.M. Feb. 1980. "Biomass Crops for California," Seminar on New Crops for California Agriculture, U.C. Davis.

The paper notes the potential of woody perennial species to produce biomass for energy production. Depending on irrigation and fertilization practices, an estimated eight to ten tons per acre of oven-dry wood may be harvested annually. Using 1.85 tons of wood per cord, that would yield 5.4 cords per acre per year.

Sands, R. 1981. "Salt Resistance in Eucalyptus camaldulensis Dehn. From Three Different Seed Sources," Aust. For. Res., 11:93-100.

Pot trials indicated that seedling survival was greatest in Lake Albacutya seed source, intermediate in Port Lincoln and lowest in Shepparton. There were no significant salt X seed source interactions and no evidence between seed sources of differential partitioning of sodium and chloride in leaves, stems and roots.

Standiford, R.B. and F.T. Ledig, technical coordinators. 1983. "Proceedings of a Workshop on Eucalyptus in California," June 14-16, 1983, Sacramento, California, Gen. Tech. Rep. PSW-69, USDA Forest Service, PSWF&RES, Berkeley, CA.

A collection of papers on species selection, products, uses, economics, growth and yield, cultural requirements, propagation, and breeding programs for eucalyptus in California.

Stewart, H.T.L. 1988. "A Review of Irrigated Forestry with Australian Tree Species," Proceedings of the International Forestry Conference for the Australian Bicentenary 1988, Australian Forest Development Institute.

A comprehensive review of the nature and extent of worldwide irrigated plantings of Australian tree species (mostly eucalyptus). This extensive review gives the results of trials for municipal and saline waste water disposal. The review includes the results of a municipal waste water use study in a semi-arid climate where monthly use was 1.4 to 1.9 pan evaporation (157 inches over the year). The paper notes that high growth rate equates to high water use.

Thomson, L.A.J. 1985. "Salt Tolerance in Eucalyptus," PhD Thesis, School of Agriculture and Forestry, University of Melbourne.

Variation in NaCl tolerance, both between and within species, was investigated using seedlings and cloned ramets under controlled laboratory conditions. Salt tolerance of red gums was additionally investigated under field conditions for survival, growth and foliage mineral composition. The investigation used 180 seed sources representing 11 species. Greater tolerances were typically exhibited by red gums like E. camaldulensis, E. wandoo and some subspecies of E. globulus. Within-species variation was so wide in some species (e.g., E. camaldulensis and E. globulus) that a general salt tolerance classification would be of little value. Field trials with E. camaldulensis, E. tereticornus and E. rudis on saline sites showed that these species are capable of growth on moderately saline soils (i.e. saturation extract EC < 10 mS/cm). Inter-specific variation may be the basis for some of the discrepancies in the literature on the comparative tolerances of eucalyptus species. Lake Albacutya provenance of E. camaldulensis was mentioned as being worthy of special consideration because of its combination of moderate salt tolerance, high growth rate, and adaptability to temperate climates.

Tribbey, B. 1988. "Biological Assessment of Evaporation Ponds," Department of Biology, California State University, Fresno.

A report prepared for the California State Conservationist, USDA, Soil Conservation Service. The report notes that evaporation ponds are presently the most feasible method for disposing of subsurface drain water, but will require around 15 to 20 percent of the treated area be dedicated for that purpose. The report documents the suitability and attractiveness of evaporation ponds for many kinds of plants and animals, and the tendency to concentrate or bioaccumulate chemicals like boron, arsenic and selenium. The report concludes that some evaporation ponds constitute an environmental hazard and makes recommendations for evaporation pond design and operation.

Tupper Tree Farms, Inc. August 1977. "An Introduction to the Mondell Pine (Pinus eldarica), a Fast Growing Tree for Dryland Areas," Tech. Rep. No. TP 77-1.

Notes the outstanding growth potential in semi-arid regions where few other coniferous species would survive. The pine has been planted in widely divergent habitats and demonstrated a tolerance for varying site conditions. Optimal growth occurred on well-drained, neutral to slightly alkaline soils, with some organic content. The pine cannot survive on poorly-drained soils, and will die if the roots are improperly aerated for an extended period of time. A number of potential industrial/commercial uses are reported.

USDI, Bureau of Reclamation, 1986, Final Environmental Impact Statement (EIS), Contingency Program for Westlands Water District Drainage Disposal Project, USDI-BOR, Sacramento, CA.

Final EIS prepared by Jones & Stokes Associates, Inc. in association with CH2M Hill and WWD. The EIS contains detailed information on drain water and the environmental effects of plugging the collection system. Additional information is included on alternatives considered but determined to be nonviable. These include evaporation basins, reverse osmosis, deep-well injection, source control and on-farm management, long-term reuse of drainage water, drainage disposal-aquatic sites, drainage disposal-terrestrial sites, drainage treatment technology, and dilution/discharge to the San Joaquin River. The only alternative judged immediately acceptable was the plugging of the collection system.

Westlands Water District. 1985. "Water Conservation and Management Handbook," Westlands Water District Publication, Fresno, CA.

Publication containing recommendations for crop & water management, irrigation scheduling, water use planning and salinity management. Projections of crop yield decrement correlated to increasing electrical conductivity are included.

Westlands Water District. 1986. "Facts and Figures," Westlands Water District Publication, Fresno, CA.

Compilation of crop water use, production, and acreage trends. Maps include areas with shallow water tables. Includes estimates that 300,000 acres will eventually need subsurface drainage and estimates of drainage water quality.

Zohar, Y. 1982. "Growth of Eucalypts on Saline Soils in the Wadi'Arava," Ilanot: The Israel Forestry Association, La-Yaaran, Vol. 32 (1/4).

The major finding of this study was that salinity tolerance will probably vary depending upon seed origin. This was demonstrated in E. occidentalis and could apply to other species. The paper recommends that for planting eucalypts on highly saline soils, seeds should be collected from saline sites occupied by the species desired. The results of natural selection could be enhanced through selection in the nursery by irrigation with increasing amounts of saline water and, after planting, by vegetative reproduction of the most resistant and fast growing trees.

APPENDIX F
REVIEWS, COMMENTS AND RESPONSES

APPENDIX F Reviews, Comments, and Responses

Reviews

Earlier drafts of the report have been reviewed by specialists in the USDA-SCS field, area, and state offices, and California Department of Food and Agriculture. Technical review and comments were requested from USDA-SCS Western National Technical Center (WNTC) and the California Evaportation Pond Coordination Group (CEPCG).

The CEPCG is an Ad-Hoc Committee formed as a result of the Kesterson problem. Review copies of the report were provided to the following agencies/individuals:

Agency/Individuals	Location
US Fish and Wildlife Service	
Harry Ohlendorf	Davis, CA
Joe Skroupa	Davis, CA
Douglas Barnum	Delano, CA
Dr. David Gilmer	Dixon, CA
Don Palawski	Sacramento, CA
US Geological Survey	
Dr. Roy Schroeder	San Diego, CA
US Dept. of Agriculture - Soil Conservation Service	
Bill Brooks	Davis, CA
CA Department of Fish & Game	
Edward Smith	Fresno, CA
Dick Daniel	Sacramento, CA
CA Regional Water Quality Control Board	
Anthony Toto	Fresno, CA
Dennis Wescott	Sacramento, CA
CA State Water Resources Control Board	
Farouk Ismail	Sacramento, CA
David Minard	Sacramento, CA
Ca Department of Water Resources	
Stephan Ford	Sacramento, CA
Lost Hills Water District	
Joseph Steele	Bakersfield, CA
San Joaquin Valley Drainage Program	
Larry Puckett	Sacramento, CA
Tulare Lake Drainage District	
Gary Rose	Corcoran, CA

Westlands Water District	
Terence Garvey	Fresno, CA
UCD-Dept. of Land, Air and Water Resource	
Kenneth Tanji	Davis, Ca
Dr. Allen Knight	Davis, Ca
CA State Univ. - Dept. of Biology	
Dr. Bert Tribbey	Fresno, CA
CA State Univ. - Dept. of Civil Engineering	
Dr. Karl Longley	Fresno, CA
Binnie California, Inc.	
Rodney Squires	Fresno, CA
Land Preservation Group	
Stephen Hall	Fresno, CA
Summers Engineering	
Joseph Summers	Hanford, CA
Individual	
William McGlasson	Fresno, CA

WRITTEN COMMENTS AND RESPONSES:

Four agencies provided written comments and can be found at the end of this appendix. The following are responses to these comments:

U.S. Department of the Interior - Fish and Wildlife Service

Comment

Although the purpose and objectives of the study have been fulfilled, we continue to be concerned with the creation of any evaporation ponds in the study area because of the contaminant problem (selenium, boron, etc.) posed to wildlife. Of the various options evaluated thus far, to dispose of drainwater, the most attractive with respect to fish and wildlife resource interests, is the agroforestry option. However, this option may be shown to have a negative value if ongoing studies determine that a woodlot irrigated with contaminated drainwater is toxic to wildlife. Additional research is needed before any definite conclusion can be made.

Response

Operation of the ponds may be done to have only summer saline water. The salt could be removed before the rains or the ponds left completely dry, thereby decreasing wildlife toxicity considerably. We need to acknowledge the plantations by themselves may be a hazard to wildlife.

Comment

Page 5, Problem Statement. This section should note that drainage water discharge to the San Joaquin River and its tributaries has increased since the cessation of discharge to the San Luis Drain.

Response

Statement Added

Comment

Page 5, Possible Current Actions. Add to this section dryland farming as a possible current action until treatment/disposal methods are environmentally acceptable.

Response

In order to grow a harvestable crop, farmers would have to fallow their fields 2 years out of every 3, in order to store soil moisture. Going to a low intensity type of farming or even returning these lands to range is always an option. However, the income reduction would be devastating.

Comment

Page 6, Future with No Action. This section indicates that ultimately many fields may go out of production without salinity and groundwater management. We suggest that a statement be included to indicate that in the event fields do go out of production, native habitat and wildlife, especially endangered species, will benefit.

Response

Statement Added

Comment

Page 5, Possible Future Actions. This section discusses possible actions intended to maintain agriculture production at approximately the present-day level, that is, continue irrigation, recycling, etc. We suggest that other actions should be included such as dry-land farming, taking a certain acreage out of production for a specific time period, enlisting land in the Conservation Reserve Program, etc. If this were done, agricultural production would be prolonged in the area until an adequate treatment solution has been developed.

Response

Dry-land farming, grazing, wildlife, etc. are always potential uses of this land. Any of these alternatives would have a devastating effect on the financial viability on the farmers of the area and their communities. The purpose of this report was to explore the economic feasibility of environmentally acceptable methods of disposing of agricultural drainwater.

California State Water Resources Control Board

Comment

Crop evapotranspiration (ET) was calculated using the modified Blaney-Criddle method. This procedure doesn't always produce reliable results, and may over- or underestimate actual ET. This could affect the estimated drainage yield used in the economic analyses. I would recommend the use of a combination-type equation if the data is available.

Response

Our experience has shown the modified Blaney-Criddle method to be appropriate to determine the average annual ET using 30 year average information.

Comment

The report does not contain a salt mass balance. I realize this was not within the scope of the study; nevertheless, I feel it may affect the results of the analysis. Discharge of concentrated brines into relatively small evaporation ponds will cause them to reach capacity (precipitate salts) much sooner than less concentrated solutions in larger ponds.

Response

A salt mass balance was not in the scope of the project, but we assumed an annual dry out of the ponds with a cleanout when the salt accumulation warrants. Leaching is designed to remove added salts. Drainage is designed to remove leached water and excess regional flow (maintain the existing water table). Salt in, less estimated use, roughly equaled salt to ponds in quick checks of the leaching percent.

Comment

The economic analysis is based on a 23-year useful life. Alternatives compared on a net present worth basis must have comparable economic lives must be based on annual cost, or other suitable measure. The question is whether or not the alternatives considered meet this criterion. I would not expect a lined evaporation pond to have the same useful life as an unlined pond, or a system with a low regional drainage yield to have the same useful life as one with a high regional drainage yield.

Response

This is correct, alternatives to be compared on a current net worth basis must have comparable economic lives. Our position is that lined and unlined evaporation ponds would have the same useful life, if they are maintained according to the maintenance schedule developed as part of the cost estimate. Similarly, systems with a high regional drainage yields would

The higher operation and maintenance costs are built into the cost estimates.

Comment

Paragraph 5 in the Summary gives two examples of evaporation ponds being replaced by eucalyptus plantation and smaller evaporation ponds. In one case, 8 acres of ponds are replaced by 18.5 acres of plantation plus ponds. In the other case, 22 acres of ponds are replaced by 24.2 acres of plantation plus ponds. I would have expected the increase to be proportionate between the two cases, and I presume the difference is explained in the underlying assumptions used in the analysis.

Response

The pond sizes represent examples from two regional drainage yield volume, high and low, that occur in the area. Summary is revised.

Comment

The report concludes that evaporation ponds alone (without agroforestry) are more cost-effective if pond linings are not required, since they allow more agricultural land to remain in production. In our experience, we know of no evaporation pond systems in the San Joaquin Valley-Tulare Lake Basin which are lined. Costs are prohibitive for most growers/agencies. Without a regulatory mandate to line evaporation ponds, there is little incentive to use agroforestry. This situation may change, however, in the future due to increasing environmental concerns over evaporation ponds.

Response

Agreed.

Comment

It is also stated that the environmental impacts of the plantation/pond alternative will be lower than evaporation ponds alone. This statement may be premature. I would expect high density eucalyptus plantation to be attractive habitat for wildlife. With the high selenium concentrations reported in the eucalyptus leaves in agroforestry plantations (up to 900 PPB), there may be some threat to wildlife.

Response

We believe there are few, if any, native species using eucalyptus leaves for a food source in possibly toxic quantities. We expect a greater effect from the leaves after they have decomposed and the salts are again available for leaching.

California Department of Food and Agriculture

Comment

(1) re. p. iv - change the text in this way:

When lined evaporation ponds are needed, the plantation/smaller pond alternative is more cost effective than evaporation ponds alone. If the ponds do not need to be clay lined, then evaporation ponds alone are more cost effective when regional drainage yield is low. If regional drainage yield is high, the plantation/smaller pond alternative is again more effective than an evaporation pond alone (see Figure C-4). The environmental impacts will be lower with the plantation/pond alternative, and the economic analysis does not reflect how important this is on a specific site.

Response

Appropriate language added

Comments

(2) Your report offers many details, and that is good. However, the text may be rather difficult to read by farmers and other people. Would you consider to publish, besides a complete report, just a four page summary with all basic findings?

Response

The River Basin Planning Staffs' Interagency Study guidance committee is the Field Advisory Committee (FAC). At the March 1, 1989, meeting, this was suggested.

Tulare Lake Drainage District

Comments

Is the 10 foot distance from tree to drain line a well established, proven safety margin or is it theoretical? This is important because of the relatively high capital cost and permanency of such an installation.

Response

The distance is based on observations made by a UCD Extension Service Forester working with eucalyptus and casurina. Observations by SCS irrigation specialist on drain pipes in orchards, support this figure. Allowing the pipe to flood during the winter period should minimize the problem.

Comments

If drain lines do become root bound, what, if any, methods are effective in clearing them?

Response

Replace plastic drains, as is the present practice. Tile drains can be cleaned.

Comments

In a given volume of irrigation water applied to a tree plantation what percent is taken up by trees and what percent migrates below the root zones? This would help establish the need, or lack thereof, for a drain field installation in tree plantation, the sizing of those systems and the intervals and volumes of water to apply.

Response

The Irrigation Water Management design provides for no more than 10% leaching to control salinity. The remainder of the water is used by the trees. The designs are made for a high water table over shallow clay, requiring a drain field.

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Division of Ecological Services
2800 Cottage Way, Room E-1803
Sacramento, California 95825

March 3, 1989

Mr. Eugene E. Andreuccetti
State Conservationist
Soil Conservation Service
United States Department of Agriculture
2121-C Street, Suite 102
Davis, California 95616-5475

Subject: USDA - Panoche Creek Salinity Draft Report

Dear Mr. Andreuccetti:

This provides comments on your draft report titled "Westwide Stream Group, Panoche Creek Salinity Study, Fresno County, California." The report concerns the economic viability of tree plantations, the potential of trees to reduce the amount of agricultural drainwater requiring disposal, and the cost effectiveness of various combinations of evaporation ponds -- both with and without tree plantations. We would like to compliment you and your staff for a report well done. The report is informative in the description of the potential options associated with the disposal of agricultural drainwater. Also, the economic evaluation of the various evaporation pond/ agroforestry options provided is an excellent analysis of the associated costs.

Although the purpose and objectives of the study have been fulfilled, we continue to be concerned with the creation of any evaporation ponds in the study area because of the contaminant problem (selenium, boron, etc.) posed to wildlife. Of the various options evaluated thus far, to dispose of drainwater, the most attractive with respect to fish and wildlife resource interests, is the agroforestry option. However, this option may be shown to have a negative value if ongoing studies determine that a woodlot irrigated with contaminated drainwater is toxic to wildlife. Additional research is needed before any definite conclusion can be made. Following are some specific comments on the text for consideration.

Page 5, Problem Statement. This section should note that drainage water discharge to the San Joaquin River and its tributaries has increased since the cessation of discharge to the San Luis Drain.

Page 5, Possible Current Actions. Add to this section dry-land farming as a possible current action until treatment/disposal methods are environmentally acceptable.

Page 6, Future With No Action. This section indicates that ultimately many fields may go out of production without salinity and groundwater management. We suggest that a statement be included to indicate that in the event fields do go out of production, native habitat and wildlife, especially endangered species, will benefit.

Page 5, Possible Future Actions. This section discusses possible actions intended to maintain agriculture production at approximately the present-day level, that is, continue irrigation, recycling, etc. We suggest that other actions should be included such as dry-land farming, taking a certain acreage out of production for a specific time period, enlisting land in the Conservation Reserve Program, etc. If this were done, agricultural production would be prolonged in the area until an adequate treatment solution has been developed.

Thank you for the opportunity to comment on your draft report. If we can be of any additional assistance, please contact Maurice Taylor of my staff.

Sincerely,

James D. Carson

James D. Carson
Acting Field Supervisor

STATE OF CALIFORNIA GEORGE DEUKMEJIAN, *Governor*

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DIVISION OF LOANS AND GRANTS
2014 T STREET
P.O. BOX 944212
SACRAMENTO, CA 94244-2120

(916) 739-4420

FEB 28 1989

Mr. Eugene E. Andreuccetti
State Conservationist
USDA - SCS
2121-C Second Street, Suite 102
Davis, CA 95616-5475

Dear Mr. Andreuccetti:

WESTSIDE STREAM GROUP, PANOCHE SALINITY STUDY, REVIEW OF DRAFT REPORT

Thank you for the opportunity to review the draft report. You have asked for our thoughts on the technical aspects of this report, and its conclusion.

The report contains a rather detailed economic analysis of a number of alternatives for agroforestry production. This is certainly a necessary first step prior to the development of commercial plantations. Due to the many variables involved in this analysis, however, I feel that the optimum combination of parameters will be somewhat site-specific, and will only be identified after a number of field trials.

Technical Aspects of Report

Crop evapotranspiration (ET) was calculated using the modified Blaney-Criddle method. This procedure doesn't always produce reliable results, and may over- or underestimate actual ET. This could affect the estimated drainage yield used in the economic analyses. I would recommend the use of a combination-type equation if the data are available.

The report does not contain a salt mass balance. I realize this was not within the scope of the study; nevertheless, I feel it may affect the results of the analysis. Discharge of concentrated brines into relatively small evaporation ponds will cause them to reach capacity (precipitate salts) much sooner than less concentrated solutions in larger ponds.

The economic analysis is based on a 23-year useful life. Alternatives compared on a net present worth basis must have comparable economic lives. Comparison of alternatives with unequal economic lives must be based on annual cost, or other suitable measure. The question is whether or not the alternatives considered meet this criterion. I would not expect a lined evaporation pond to have the same useful life as an unlined pond, or a system with a low regional drainage yield to have the same useful life as one with a high regional drainage yield.

Mr. Andreuccetti

Paragraph 5 in the Summary gives two examples of evaporation ponds being replaced by eucalyptus plantations and smaller evaporation ponds. In one case, 8 acres of ponds are replaced by 18.5 acres of plantation plus ponds. In the other case, 22 acres of ponds are replaced by 24.2 acres of plantation plus ponds. I would have expected the increase to be proportionate between the two cases, and I presume the difference is explained in the underlying assumptions used in the analysis.

Conclusion of Report

The report concludes that evaporation ponds alone (without agroforestry) are more cost-effective if pond linings are not required, since they allow more agricultural land to remain in production. In our experience, we know of no evaporation pond systems in the San Joaquin Valley - Tulare Lake Basin which are lined. Costs are prohibitive for most growers/agencies. Without a regulatory mandate to line evaporation ponds, there is little incentive to use agroforestry. This situation may change, however, in the future due to increasing environmental concerns over evaporation ponds.

It is also stated that the environmental impacts of the plantation/pond alternative will be lower than evaporation ponds alone. This statement may be premature. I would expect high density eucalyptus plantations to be attractive habitat for wildlife. With the high selenium concentrations reported in the eucalyptus leaves in agroforestry plantations (up to 900 ppb), there may be some threat to wildlife.

Thank you again for the opportunity to review this report. I hope my comments have been helpful. If we can be of further assistance, please call Walt Shannon at (916) 739-4420.

Sincerely,

Farouk T. Ismail, PhD., P.E.
Chief, Technical Support Section

cc: Vashek Cervinka
California Department of
Food and Agriculture
1220 N Street
Sacramento, CA 95814

STATE OF CALIFORNIA GEORGE DEUKMEJIAN, *Governor*

DEPARTMENT OF FOOD AND AGRICULTURE

1220 N Street
Sacramento, CA 95814

February 22, 1989

Mr. Randall Godden
USDA-Soil Conservation Service
Davis, California 95616

Dear Randy:

Many thanks for giving me an opportunity to review the final draft report "Westside Stream Group Panoche Creek Salinity Study". I have these suggestions:

(1) re. p.iv - change the text in this way:

When lined evaporation ponds are needed, the plantation/smaller pond alternative is more cost effective than evaporation ponds alone. If the ponds do not need to be clay lined, then evaporation ponds alone are more cost effective when regional drainage yield is low. If regional drainage yield is high, the plantation/smaller pond alternative is again more effective than an evaporation pond alone (see please Figure C-4). The environmental impacts will be lower with the plantation/pond alternative, and the economic analysis does not reflect how important this is on a specific site.

(2) Your report offers many details, and that is good. However, the text may be rather difficult to read by farmers and other people. Would you consider to publish, besides a complete report, just a four page summary with all basic findings?

With best regards,

Vashek Cervinka
Research Manager
Agricultural Resources Branch
(916) 445-6719

TULARE LAKE DRAINAGE DISTRICT

POST OFFICE BOX 985
CORCORAN, CALIFORNIA 93212
TELEPHONE: 992-3145

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February 6, 1989

Mr. Eugene E. Andreuccetti
2121-C Second St., Suite 102
Davis, CA 95616-5475

Mr. Andreuccetti:

After having reviewed the Draft Report on the Panoche Creek Salinity Study and based on our experience with our own agroforestry project, I see a need for further, more in-depth research in a couple of areas.

Some questions that come to mind are:

1. Is the 10 foot distance from tree to drain line a well established, proven safety margin or is it theoretical? This is important because of the relatively high capital cost and permanency of such an installation.

2. If drain lines do become root bound, what, if any, methods are effective in clearing them?

3. In a given volume of irrigation water applied to a tree plantation what percent is taken up by trees and what percent migrates below the root zones? This would help establish the need, or lack thereof, for a drain field installation in tree plantations, the sizing of those systems and the intervals and volumes of water to apply.

We view agroforestry as one of the most viable alternatives of managing subsurface agriculture drainage waters. There is a definite need to accelerate research of this concept.

Very truly yours,

TULARE LAKE DRAINAGE DISTRICT

Gary K. Rose

Gary K. Rose
Manager

GKR/mg

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